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Industrial QUALITY CONTROL

Vol. XV, No. 1, July 1958

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Life Testing and the Exponential Distribution

More Effective SQC

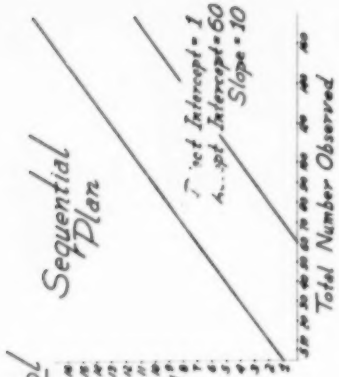
The QC Budget

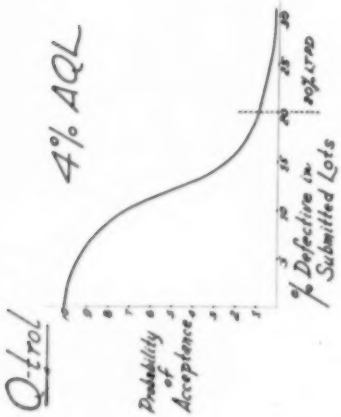
Experimental Methods of Determining Optimum Operating Conditions — Part II-1

QUALITY through Scientific Methods

Journal of the AMERICAN SOCIETY FOR QUALITY CONTROL

The new Q-trol offers simplicity of operation. It is an important step forward in electronic quality control.





Many concepts of Statistical Quality Control applicable in your business have been by-passed due to their theoretical complexity. Others, approximated to permit application, have lost a considerable portion of their value. The accelerated production rates which are developing, and mechanized processes which are here, have caused many manual statistical quality control techniques to approach obsolete status. The era of mechanization draws near, advanced techniques are continuously developed, and qualified personnel are becoming more scarce, creating new problems that TEPCOR can now meet with a series of automatic quality control computers. These are the result of a research and development program begun in 1955.

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ASQC Convention Exposition Chart

13TH ANNUAL CONVENTION AND NATIONAL ALL-INDUSTRY QUALITY CONTROL & PRODUCTION EXPOSITION CLEVELAND PUBLIC AUDITORIUM MAY 25-27, 1959

With plans for the American Society for Quality Control 13th Annual Convention and National All-Industry Quality Control & Production Exposition, May 25-27, rolling ahead at top speed, the committee is rapidly gathering momentum to make this the biggest show in the history of ASQC.

Wade R. Weaver of Republic Steel, the General Chairman of the Convention and Exposition, has signed contracts for 28,000 square feet of exhibit space in the Exhibition Hall of Cleveland's huge Public Auditorium. It is here in the auditorium's main arena where the daily luncheons will be held. The technical sessions will also be conducted in the auditorium's large conference rooms, bringing all of the convention's activities under one roof.

Sam Troxel of the Ohio Bell Telephone Co., and Ray Marks, of the Ford Motor Co., are putting together a colorful series of social and sightseeing events for the ladies. There will be chartered bus trips to some of Cleveland's outstanding historical and civic centers, such as the city's national ranking Museum of Art at the famed University Circle where Western Reserve University and Case Tech are located. It will be a program of activities that will hold the ladies' interests from morning 'til the dinner hour when they again join their husbands. And of course, time will be allowed for them to shop in Cleveland's many outstanding department stores for those family gifts and souvenirs.

Howard Coughlin of Thompson Products Co., our Program Chairman, has a number of national personalities lined up to speak at the daily luncheons. His technical session panel programs are rapidly being crystalized.

Howard Schmidt of Alcoa, has a number of Cleveland's top industries arranging special plant tours for convention visitors who like to peek in and see what and how the other fellow does it. These should be of unusual interest to QC'ers as Cleveland is internationally known as a center not only for the tool industry but automotive, aircraft, missiles, and heavy, as well as scores of light, industries. It is the home of numerous research laboratories, including the world famous $150,000,000 Lewis Research Center of NASA. This center is sure to be among the plants on display.

The theme of the convention this year will be "Q to Quality" and there's little doubt that this tricky expression will catch on as a byword.

There's great interest in the exposition this year and the committee expects to have many new concerns among those with displays. Not only is the convention growing from year to year in membership attendance but the Society is gaining greater prestige among industrial executives and industry itself.

"Q to Quality" is becoming a recognized fact. Why not make sure your concern, or that firm which sells you QC items and equipment, is among the exhibitors.

Andrews, Bartlett and Associates, Inc., 1849 W. 24th St., Cleveland 13, Ohio, are again in charge of the exposition and they will be happy to send you a folder and rates on request. Talk it up. Let's make this a really big show.

Hotel Cleveland will be the headquarters for the convention this year. This hotel is a unit of the well-known Terminal grouping on Cleveland's Public Square in the heart of the city. The main downtown union depot of all railroads, except the Pennsylvania, is the terminal so that if you arrive by train you have only to walk through the concourse to the hotel.

Those coming by plane will arrive at Cleveland-Hopkins Airport, which is about 30 minutes from the hotel by airport limousine and the Greyhound Bus Depot, a brand new modern building, is just five minutes away. Whatever way you travel it's a convenient location. And we might add, you'll find ample outside or inside parking for your cars, a service of the hotel.

Perhaps many of you think the name National All-Industry Quality Control & Production Exposition is by far too long. At least too cumbersome to say. But, believe us, it was chosen after many hours of thought and brain-storming sessions and we believe it properly covers the true breadth of our profession.

Shorten it if you like, but don't fail to cover everything we now do if you're going to rename our exposition. Remember the scope of our show is being broadened. Let's hear your suggestions.

To promote our show and convention this year we are carrying out a planned program of promotion and publicity which is geared to reach into most trade publications and the daily newspapers.

Since it is almost impossible to collect all of the stories which are released each month, through a clipping service, we would appreciate it if you would watch for these stories and send them to us. Just mail them to Wade Weaver, Republic Steel, Cleveland 1, Ohio. Thanks.

It's going to be a great convention and exposition. So start NOW making your plans to be in Cleveland.

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the Exponential Distribution *and its role in life testing**

BENJAMIN EPSTEIN

Wayne State and Stanford Universities

Introduction

Many current results in life testing are based on the assumption that the life X is described by a probability density function $f(x;\theta)$ of the form

$$f(x;\theta) = \frac{1}{\theta}\exp[-x/\theta] \qquad x>0,\ \theta>0 \quad (1)$$

In (1), x is life measured in appropriate units (for example, hours) and

$$E(X) = \int_0^\infty xf(x;\theta)dx = \int_0^\infty \frac{x}{\theta}\exp[-x/\theta]dx = \theta \quad (2)$$

is the mean life expressed in appropriate units. There is evidence that the lives of electron tubes or the time intervals between successive breakdowns of electronic systems are, to a first approximation, random variables having the density (1).

A partial justification for the assumption of an exponential probability density function (p.d.f.) has been discussed in some detail in a paper by the author[12,13] and by D. J. Davis[7] and several relevant references may be found in these papers. Further evidence of an empirical nature can be found in a recent series of ARINC monographs.[1] We are well aware of the fact that many life distributions are not adequately described by equation (1). Although this may be the case, an understanding of the theory in the exponential case is essential if we are to treat more general situations.

Some six years have elapsed since we started research on statistical methods in life testing. At the beginning, some basic questions arose as to where to concentrate our efforts since there were many avenues open for research activity. The exponential distribution was chosen only after considerable discussion with people in the field of electronics and after a study of the literature existing and available at that time. In retrospect, the choice of the exponential distribution was a good one. It seems as though the exponential distribution plays a role in life testing analogous to that of the normal distribution in other areas of statistics. It is our feeling that in many cases there is as much justification for using the exponential distribution in life test situations as there is for using the normal distribution, for example, in developing sampling plans by variables.

An important by-product of the assumption of the exponential distribution of life is that it makes it possible to apply the well developed theory of Poisson processes. Furthermore, one can, by almost trivial changes, generalize all the results to the case where the conditional rate of failure is some function of time $Z(t)$, rather than a constant, as in the exponential case. The theory, thus extended, has validity over a wide area including most cases of practical interest.

Poisson Processes and Exponential Models†

We now consider in some detail why one might expect the exponential distribution to occur and what implications the assumption of an exponential distribution carries with it. In addition, we will mention why one might also expect certain other distributions to occur in life test situations.

One often refers to the exponential distribution as corresponding to a purely random failure pattern. Precisely what one means mathematically is that whatever is causing the failure occurs according to a Poisson process with some rate, λ. For example, if we imagine that a failure occurs whenever a Geiger counter is actuated by a radioactive source having an emission rate, λ, then the distribution of time intervals between successive failures will be given by the p.d.f. $\lambda e^{-\lambda t}$, $\lambda>0$, $t>0$. This is very easy to prove. Let T be the random variable associated with the time interval between successive events; then

$$\Pr(T>t) = \Pr[\text{no event occurs in the interval } (0,t)] \quad (3)$$

where

$t = 0$ is the time when the most recent event occurred.

From the Poisson assumption,

$$\Pr(T>t) = e^{-\lambda t} \quad (4)$$

*Work done with partial support from the Office of Naval Research, under Contract Nonr-2163(00) (NR-042-018). Reproduction in whole or in part is permitted for any purpose of the United States Government.

†For a detailed treatment of Poisson processes and exponential distributions see Feller.[14]

Thus

$$\Pr(T \leq t) = 1 - e^{-\lambda t} \tag{5}$$

and the p.d.f. is given by

$$f(t) = \lambda e^{-\lambda t} \qquad \lambda > 0,\ t > 0 \tag{6}$$

The question naturally arises as to whether this rather artificial model has any relevance to a real life situation. The answer is that it may, under the following sort of conditions. Imagine a situation where a device under test is being subjected to an environment E, which is some sort of random process. Let us imagine that this random process has peaks distributed in a Poisson manner and that it is only these peaks that can affect the device, in the sense that the device will fail if a peak occurs and will not fail otherwise. If this is the situation, and if peaks in the stochastic process describing the environment occur with Poisson rate, λ, then the failure distribution for the devices under test will be given by the p.d.f. (6). It is interesting to note that while we call (6) a failure distribution, it describes, in reality, the frequency of severe shocks in the environment. This is precisely what (6) means in the all-or-none situation, where the device fails if and only if a peak occurs and not otherwise.

It is not necessary, in the preceding discussion, that we have an all-or-none situation in order that the exponential distribution arise. Suppose, as before, that peaks in the stochastic process occur with rate λ and that the conditional probability that the device fails, given that a peak has occurred, is p. Then it is clear that the event: "device does not fail in time t" is composed of the mutually exclusive events, "no peak occurs in (0,t)," "one peak occurs and device does not fail, given this peak," "two peaks occur and device does not fail, given these two peaks," etc. Symbolically we have

$$\begin{aligned}\Pr(T > t) &= e^{-\lambda t} + q(\lambda t)e^{-\lambda t} + q^2\frac{(\lambda t)^2}{2!}e^{-\lambda t} \\ &\quad + \ldots + q^k\frac{(\lambda t)^k}{k!}e^{-\lambda t} + \ldots \\ &= e^{-\lambda t}\left[1 + q\lambda t + \frac{(q\lambda t)^2}{2!} + \ldots \right. \\ &\quad \left. + \frac{(q\lambda t)^k}{k!} + \ldots\right] \\ &= e^{-\lambda t + q\lambda t} = e^{-\lambda t(1-q)t} = e^{-\lambda p t}\end{aligned} \tag{7}$$

Thus

$$\Pr(T \leq t) = 1 - e^{-\lambda p t} \tag{8}$$

and

$$f(t) = \lambda p e^{-\lambda p t} \qquad t > 0 \tag{9}$$

Again we have an exponential distribution. It is interesting to note that the exponent λp (which is the reciprocal of the mean time between failures) reflects the simplest kind of interaction between the device being tested and its environment. If we had two kinds of devices D_1 and D_2 each subjected to the same environment E, and if p_1 is the conditional probability that D_1 will fail, given that a peak in E has occurred, and p_2 is the conditional probability that D_2 will fail, given that a peak in E occurs, then the reciprocal of the mean time between failures is given by λp_1 and λp_2 respectively. If $\lambda p_1 < \lambda p_2$, then one can say that in environment E, the device D_1 is stronger than the device D_2.

Carrying these ideas further, suppose that an item is exposed simultaneously to k environments $E_1, E_2, \ldots, E_k$. Suppose that the environment E_i is characterized by a rate λ_i (the frequency with which dangerous peaks occur in environment E_i) and that the conditional probability that the device fails, given that a peak has occurred is p_i. From (7) it follows that the probability that a device survives environment E_i for a length of time t is given by $\exp[-\lambda_i p_i t]$. Let us assume that the environments are described by stochastic processes which operate independently of one another, then from (7) and the assumption of independence, the time T until a failure occurs (or the time between failures) is a random variable such that

$$\Pr(T > t) = \prod_{i=1}^{n} \exp[-\lambda_i p_i t] = \exp\left[-\left(\sum_{i=1}^{n}\lambda_i p_i\right)t\right] \tag{10}$$

Defining

$$\Lambda = \sum_{i=1}^{n} \lambda_i p_i$$

(10) becomes

$$\Pr(T > t) = e^{-\Lambda t} \tag{11}$$

and consequently

$$\Pr(T \leq t) = 1 - e^{-\Lambda t} \qquad t \geq 0 \tag{12}$$

Thus we again have an exponential distribution.

In the situation described by the distribution function (8) and density function (9), p, the conditional probability that a failure occurs, given that a peak has occurred, is independent of t. Given that a peak occurs, let us now assume that the conditional probability that a failure occurs is given by p(t). It is easy to show in this case that

$$\Pr(T > t) = \exp\left[-\lambda \int_0^t p(\tau)\,d\tau\right] \tag{13}$$

and so

$$\Pr(T \leq t) = 1 - \exp\left[-\lambda \int_0^t p(\tau)\,d\tau\right] \tag{14}$$

and

$$\begin{aligned} f(t) &= \lambda p(t)\exp\left[-\lambda \int_0^t p(\tau)\,d\tau\right] \\ &= \lambda p(t)\exp[-\lambda P(t)] \qquad t \geq 0 \end{aligned} \tag{15}$$

where

$$P(t) = \int_0^t p(\tau)\,d\tau. \tag{16}$$

Illustrations

1. In particular suppose that

$$p(\tau) = 0 \qquad 0 \leq \tau < A$$

$$p(\tau) = 1 \qquad \tau \geq A$$

then

$$\Pr(T \leq t) = 0 \qquad t < A$$

$$= 1 - e^{-\lambda(t-A)} \qquad t \geq A$$

and

$$f(t) = 0 \qquad t < A$$

$$= \lambda e^{-\lambda(t-A)} \qquad t \geq A$$

This is known as the two parameter exponential.

2. Another example is of the following kind:

$$p(\tau) = \left(\frac{\tau}{t_0}\right)^{\alpha} \qquad 0 \leq \tau < t_0$$

$$= 1 \qquad \tau \geq t_0$$

In this case

$$\Pr(T \leq t) = 1 - \exp\left[-\frac{\lambda t^{\alpha+1}}{(\alpha+1)t_0^{\alpha}}\right] \qquad 0 \leq t < t_0$$

$$= 1 - \exp\left[-\lambda\left(t - \frac{\alpha}{\alpha+1}t_0\right)\right] \qquad t \geq t_0$$

Remark: In the range, $0 \leq t < t_0$, $\Pr(T \leq t)$ is of the form frequently called a Weibull distribution.

A generalization in still another direction is to assume that devices are exposed to a variety of environments. For example, we could imagine a situation where devices are exposed to k possible environments $E_1, E_2, \ldots, E_k$ which can occur with respective probabilities $c_1, c_2, \ldots, c_k (c_j \geq 0, \sum_{j=1}^{k} c_j = 1)$. Furthermore, with each environment E_j there is associated a λ_j (the rate at which dangerous peaks occur in environment E_j) and within the environment E_j, the conditional probability that a device fails, given that a peak occurs is p_j. It then follows quite readily that the probability of surviving for a length of time t is given by

$$\Pr(T > t) = \sum_{j=1}^{k} c_j \exp[-\lambda_j p_j t] \qquad (17)$$

The associated density function is described by

$$f(t) = \sum_{j=1}^{k} c_j \lambda_j p_j \exp[-\lambda_j p_j t]$$

$$= \sum_{j=1}^{k} c_j \nu_j \exp[-\nu_j t] \qquad (18)$$

where

$$\nu_j = \lambda_j p_j$$

Thus we are led to a description of the density of failure times as a sum of exponentials. A continuous analogue of (18) is

$$f(t) = \int_0^{\infty} \nu e^{-\nu t}\, dG(\nu) \qquad (19)$$

It is interesting to see what happens in the special case for which

$$g(\nu) = \frac{dG(\nu)}{d\nu} = \frac{\nu^r A^{r+1} e^{-A\nu}}{r!} \qquad 0 \leq \nu < \infty \quad (20)$$

Equation (19) then becomes

$$f(t) = \int_0^{\infty} \frac{\nu^{r+1} A^{r+1} e^{-\nu(A+t)} d\nu}{r!} \qquad (21)$$

It is readily verified that f(t) becomes

$$f(t) = \frac{(r+1)\ A^{r+1}}{(A+t)^{r+2}} \qquad t > 0 \quad (22)$$

Remark: It is interesting to note that in the special case where $A = r+1$, f(t) becomes an $F(2, 2r+2)$ distribution.

Thus, the assumption that failure is associated in an essential way with the occurrence of peaks in a Poisson process has led us to a number of quite interesting life distributions.

Model Based on Conditional Probability of Failure

Let us now proceed in a different direction and see where this leads us. It is well-known that if the underlying distribution of life T is described by the exponential p.d.f. $f(t;\theta) = \frac{1}{\theta} e^{-t/\theta}$, then the conditional probability of an item failing in the time interval $(t, t+\Delta t)$, given that it has survived for time t, is independent of t. This is readily verified since

$$\Pr(t < T < t + \Delta t | T > t) = f(t;\theta)\Delta t / 1 - F(t;\theta)$$

$$= \frac{1}{\theta} e^{-t/\theta} \Delta t / e^{-t/\theta} = \Delta t / \theta \qquad (23)$$

Generally speaking the conditional rate of failure, or hazard rate, g(t), where

$$g(t) = f(t)/[1 - F(t)] \qquad (24)$$

does depend on t. We are interested in solving for f(t) and F(t), given the failure rate, g(t). This is readily done since (24) implies that

$$d\{\ln[1 - F(t)]\} = -g(t) \qquad (25)$$

and therefore, recalling that $F(0) = 0$,

$$F(t) = 1 - \exp\left[-\int_0^t g(\tau)d\tau\right]$$

$$= 1 - e^{-G(t)} \qquad t \geq 0 \quad (26)$$

where

$$G(t) = \int_0^t g(\tau)d\tau$$

The density function f(t) is obtained by differentiation and is

$$f(t) = g(t)\exp\left[-\int_0^t g(\tau)d\tau\right] \qquad t \geq 0 \quad (27)$$

Illustrations

Example 1. Suppose that

$$g(t) \equiv \frac{1}{\theta} \qquad t \geq 0$$

then (26) becomes

$$F_{\theta}(t) = 0 \qquad t < 0$$

$$= 1 - e^{-t/\theta} \qquad t \geq 0$$

and (27) becomes

$$f_{\theta}(t) = \frac{1}{\theta} e^{-t/\theta} \qquad t \geq 0$$

$$= 0 \qquad \text{elsewhere}$$

This is the exponential distribution.

Example 2. Suppose that

$$g(t) = 0 \qquad 0 \leq t < A$$

$$= \frac{1}{\theta} \qquad t \geq A$$

In this case we get the two-parameter exponential distribution where (26) becomes

$$F_a(t) = 0 \qquad t<A$$
$$= 1 - \exp\left[-\left(\frac{t-A}{\theta}\right)\right] \qquad t\geq A$$

and (27) becomes

$$f_a(t) = 0 \qquad t<A$$
$$= \frac{1}{\theta}\exp\left[-\left(\frac{t-A}{\theta}\right)\right] \qquad t\geq A$$

Example 3. Suppose that $g(t) = kt^{k-1}/\theta^k$, where $k>0$. In this case, (26) becomes

$$F_a(t) = 0 \qquad t<0$$
$$= 1 - \exp\left[-\left(\frac{t}{\theta}\right)^k\right] \qquad t\geq 0$$

and (27) becomes

$$f_a(t) = \frac{kt^{(k-1)}}{\theta^k}\exp\left[-\left(\frac{t}{\theta}\right)^k\right] \qquad t\geq 0$$
$$= 0 \qquad \text{elsewhere}$$

Remark: This distribution is often called the Weibull distribution. Note that the conditional rate of failure $g(t)$ is

decreasing if $0<k<1$

constant if $k = 1$

increasing if $k>1$.

Example 4: Suppose that $g(t) = \alpha\beta e^{\beta t}$. In this case, $G(t) = \alpha(e^{\beta t}-1)$.

Thus (26) becomes

$$F(t) = 0 \qquad t<0$$
$$= 1 - \exp[-\alpha(e^{\beta t}-1)] \qquad t\geq 0$$

and (27) becomes

$$f(t) = \alpha\beta e^{\beta t}\exp[-\alpha(e^{\beta t}-1)] \qquad t\geq 0$$

Remark: This kind of distribution occurs in extreme value theory.[16]

It should be noted that there is a great deal of similarity between formulas (14) and (26). Actually, these two models have a great deal in common, the difference being only that in one model we make specific assumptions regarding an underlying Poisson process which generates dangerous peaks, whereas in the second model the conditional rate of failure function, $g(t)$, is made central to the discussion. $g(t)$ depends on the environment, on the items under test, and on the interaction between items being tested and the environment. If we try to make explicit the dependence of $g(t)$ on the environment, we will be led back, essentially, to the first model. It is also interesting to note that we are led to distributions which are in a sense rather direct generalizations of the simple exponential distribution. This is very important because this makes it possible to change the time scale in such a way that all theoretical results obtained under a purely exponential hypothesis are valid for the more general situation. Thus, in the second model, if t represents the time to failure, then $u = G(t) = \int_0^t g(\tau)d\tau$ is distributed with c.d.f. $1 - e^{-u}$, $u\geq 0$, and with p.d.f. e^{-u}, $u\geq 0$. As a consequence of this, many of the theorems, tests, estimation procedures, formulas, etc., become valid in a much more general situation if one replaces failure times t_i by generalized times, $u_i = G(t_i)$.

Another interesting feature of the models is that they lead to all kinds of useful distributions, some of which arise in other connections. As examples, we mention the so-called Weibull distributions and extreme value distributions.

Two Other Failure Models

We now consider briefly two other models. In the first of these, let us assume that a device subject to an environment E will fail when exactly $k\geq 1$ shocks occur and not before. If shocks occur at a Poisson rate λ, then the waiting time T_k (or life) until the item fails is described by the p.d.f.

$$f_k(t) = \frac{\lambda^k t^{k-1}e^{-\lambda t}}{(k-1)!} \qquad t>0 \qquad (28)$$
$$= 0 \qquad \text{elsewhere}$$

and by the c.d.f.

$$F_k(t) = \Pr(T_k\leq t) = \sum_{j=k}^{\infty}\frac{e^{-\lambda t}(\lambda t)^j}{j!} \qquad (29)$$

The derivations of (28) and (29) are simple. Thus to get $f_k(t)$ we note that

$$\Pr(t<T_k<t+\Delta t) = \Pr[\text{exactly } (k-1) \text{ shocks in } (0,t) \text{ and 1 shock in } (t,t+\Delta t)]$$
$$= \frac{(\lambda t)^{k-1}e^{-\lambda t}}{(k-1)!}\lambda\Delta t \qquad (30)$$

Hence

$$f(t) = \frac{\lambda^k t^{k-1}e^{-\lambda t}}{(k-1)!} \qquad t>0$$

To derive $F_k(t)$ we note that

$$\Pr(T_k>t) = \Pr[k-1 \text{ or fewer failures in } (0,t)]$$
$$= \sum_{j=0}^{k-1}\frac{e^{-\lambda t}(\lambda t)^j}{j!} \qquad (31)$$

Therefore,

$$F_k(t) = \Pr(T_k\leq t) = 1 - \Pr(T_k>t)$$
$$= 1 - \sum_{j=0}^{k-1}\frac{e^{-\lambda t}(\lambda t)^j}{j!}$$
$$= \sum_{j=k}^{\infty}\frac{e^{-\lambda t}(\lambda t)^j}{j!} \qquad (32)$$

For the special case where $k = 1$, (28) and (29) become (6) and (7), respectively.

It is quite clear that formulas (8), (9), (10), (11), (14), (15), and (19) can all be suitably generalized to the case where the life time is given by T_k and not by

T_i. Thus, for example, the analogues of (14) and (15) become

$$\Pr(T_k \leq t) = 1 - \sum_{j=0}^{k-1} \frac{e^{-\lambda P(t)}[\lambda P(t)]^j}{j!} = \sum_{j=k}^{\infty} \frac{e^{-\lambda P(t)}[\lambda P(t)]^j}{j!} \tag{33}$$

and

$$f_k(t) = \frac{[\lambda P(t)]^{k-1} e^{-\lambda P(t)} \lambda p(t)}{(k-1)!} \tag{34}$$

In essence, one can say that this simple model gives rise to the Type III distribution and its generalizations.

We have seen in our earlier models that under certain assumptions one gets the Weibull and extreme value distributions as possible life distributions. We should now like to examine the relevance of an extreme value model. It is our feeling that what we are saying applies to failure problems involving corrosion. Suppose, for example, that corrosion is essentially a pitting phenomenon and that failure is associated with perforation at the deepest pit. The time to failure may then be viewed as follows: let t_i be the time required to perforate the material at the i^{th} pit. Then the time to failure is min (t_i). If the pit depths follow an exponential distribution, and if we assume that time to perforation at a pit is linearly dependent on the thickness of the coating minus the pit depth, then extreme value theory would lead one to expect a lifetime distribution of the form $A \exp(t) \exp[-Ae^t]$.[2,8]

For further details on extreme values in this connection one should see papers by Epstein,[9,10] Epstein and Brooks,[11] and Gumbel.[15,16]

Remark 1: There have recently appeared results in the literature indicating that failures of complex mechanisms tend to be exponentially distributed. This has a theoretical justification since the times between failures of the complex mechanism (we are assuming that it is repaired after it breaks down and put back into service) result from a superposition of the failure patterns of the parts making up the mechanism. It has been shown by D. R. Cox and W. L. Smith[5,6] that to a good approximation this kind of superposition gives rise to an exponential distribution of times between successive breakdowns.

Remark 2: It will be noted in the foregoing that none of the failure models led to a normal or logarithmic normal distribution of life. How, then, does one explain the fact that some observed lifetime distributions appear to be normal or logarithmic-normal? It seems to us that in our considerations we have assumed that in one way or another sudden shocks in the environment were important. If this is the case, then one must be led to the exponential distribution or suitable generalizations of it. But if failure is caused by a wear-out mechanism or is a consequence of accumulated wear, then we assert that the normal distribution can be expected. Thus, if an accumulation of k failures is required for failure, we have been led to a type III distribution which will tend to normality for k large.

Another possibility is that failure occurs after an essential substance has been used up. In this case, the time to failure might be proportional to the amount of this substance in the particular specimens being tested. If the amount of the substance varies from specimen to specimen according to a normal distribution, then one would get a normal distribution of life times.

What about logarithmic normal distributions? It seems to us that such a distribution can arise in either of two ways:

(i) as an approximate fit to skewed distributions like the Weibull or type III, or

(ii) if failure depends on using up some critical substance, the amount of which varies according to a logarithmic normal distribution from specimen to specimen.

It may be noted that the logarithmic normal distribution of lives seems to occur particularly in some biological problems. Whether this results in accordance with (i) or (ii) is generally not clear.

Remark 3: It is interesting to note that the failure distribution given by (34) is almost identical with the one given by Z. W. Birnbaum and S. C. Saunders[3] in their recent paper in which they give a statistical model for life-length of structures under dynamic loading (i.e., fatigue). One difference is that they make the conditional rate of failure function central to their discussion while we make more explicit use of the underlying Poisson process generating dangerous peaks. The other difference is that they are dealing with a multi-component structure, which initially has m components. They assume further that, in the course of time, one component after another fails and that there is a critical number of failures $k \leq m$, such that the entire structure fails when k of its components fail. The analogue of their Assumption B, if one uses the Poisson model, is the following: if a peak in the stochastic process (the peaks are assumed to occur at rate λ) occurs at time t and if j of the components in the structure have failed prior to time t, then each of the remaining $(m-j)$ components has a conditional probability of failure given by $p(t)/(m-j)$. It is then very easy to show that the p.d.f. of S_k, the life of structure, is given by (34) and further that $2\lambda \int_0^{S_k} p(\tau)d\tau$ is distributed as $\chi^2(2k)$. This is an analogue of the theorem given on p. 154 of Ref. (3).

Remark 4: We have shown in this article that a possible theory of failure is based on the Poisson process. A generalization of Poisson processes is given by "birth and death" processes. It has recently been shown in a note by Weiss[17] that some kinds of mechanical failure, such as creep failure of oriented polymeric filaments under tensile stresses, (see Coleman[4]) can be viewed as "pure death" processes. Essentially the theory assumes that there are initially N_0 fibers, each of which, independent of the other fibers, is subject to failure under load. Failure occurs when all the fibers have failed. Two special cases are considered:

(i) the probability of a single fiber failing in the time interval $(t, t + \Delta t)$ is given by $\psi(t)\Delta t$;

(ii) the probability of a single fiber failing in $(t, t + \Delta t)$ when $n(\leq N_0)$ fibers are left is given by

$$\frac{N_0}{n} \psi(t)\Delta t$$

A "pure death" process where the probability of a fiber failing is given by (i) results in the following life distribution:

$$\Pr(T \leq t) = \Pr(0 \text{ fibres survive time } t) = \{1 - \exp[-\int_0^t \psi(\tau)d\tau]\}^{N_0} \tag{35}$$

The p.d.f. of T is given by

$$f(t) = N_0 \psi(t) \exp[-\int_0^t \psi(\tau)d\tau] \times \{1 - \exp[-\int_0^t \psi(\tau)d\tau]\}^{N_0-1} \quad (36)$$

In the special case where

$$\psi(\tau) \equiv \lambda \qquad \tau>0$$

then (35) becomes

$$Pr(T \leq t) = [1 - e^{-\lambda t}]^{N_0} \quad (35')$$

and (36) becomes

$$f(t) = N_0\lambda e^{-t}[1 - e^{-\lambda t}]^{N_0-1} \quad (36')$$

Furthermore

$$E_\lambda(T) = \lambda[1 + \tfrac{1}{2} + \ldots + \frac{1}{N_0}] \cong \frac{\log N_0}{\lambda} \quad (37)$$

A "pure death" process where the probability of a fiber failing is given by (ii) results in the life distribution:

$$Pr(T \leq t) = Pr(0 \text{ fibers survive time } t) = 1 - \sum_{j=0}^{N_0-1} \frac{[\int_0^t N_0\psi(\tau)d\tau]^j}{j!} \exp\left[-\int_0^t N_0\psi(\tau)d\tau\right] \quad (38)$$

The p.d.f. of T is given by

$$f(t) = \left[\int_0^t N_0\psi(\tau)d\tau\right]^{N_0-1} \frac{N_0\psi(t)}{(N_0-1)!} \exp\left[-\int_0^t N_0\psi(\tau)d\tau\right] \quad (39)$$

In particular, if

$$\psi(\tau) \equiv \lambda \qquad \tau>0$$

then (38) and (39) become

$$Pr(T \leq t) = 1 - \sum_{j=0}^{N-1} \frac{(N_0\lambda t)^j}{j!} \exp[-N_0\lambda t] \quad (38')$$

and

$$f(t) = N_0\lambda \frac{(N_0\lambda t)^{N_0-1}}{(N_0-1)!} \exp[-N_0\lambda t] \quad (39')$$

Further

$$E_\lambda(T) = \frac{1}{\lambda} \quad (40)$$

It should be noted that assumption (ii) in the Weiss model is essentially the same as assumption B in the Birnbaum-Saunder paper and hence the p.d.f.'s of life which result must agree. It should also be noted that (36) is the p.d.f. of the largest value in a sample of size N_0 drawn from a distribution with c.d.f. $1-\exp[-\int_0^t \psi(\tau)d\tau]$, while (39) is a Type III distribution.

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SQC can be made *more* effective

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Introduction

Quality requirements on manufactured goods in almost all industries have steadily increased over the past years. As the supply surpasses the demand for products in some industries, competition creates strong pressures for better quality and for lower manufacturing costs. The current pressures for more reliable military products are well-known to all of us. A science of quality control has evolved and grown at a speed, at least sufficient, to meet all these challenges of higher quality standards, lower production costs, and more reliable product. Stimulated by the thinking of Walter Shewhart in his memorable book *Economic Control of Quality of Manufactured Product* and by the new sampling concepts of Dodge and Romig, the control chart and the acceptance sampling plans became the nucleus for the new science. Tremendous technological progress in measurement equipment, the establishment of basic principles with regard to the quality control function and its place in industrial organization, and a gradual absorption of more and more of the existing and growing body of modern statistical principles and methodology have brought the science of quality control to its present stage of evolution.

The tremendous contribution of the quality control science to modern industry is quite generally acknowledged and accepted. Most of us who have entered the quality control engineering profession can point with pride to one or more particular applications of SQC principles and techniques which have resulted in many tangible benefits to our companies. We look with admiration at a few companies which have been using this new science to its full potential and have been getting exceedingly profitable results.

It appears strange, then, that when asked to recommend a number of companies which might serve as examples of quality control progress, we find it difficult to add many names to a relatively short basic list. It would be interesting to note how many of us would add the names of the companies in which we have quality control responsibilities. The explanation must lie in the fact that while there has been some QC progress in most companies, it is quite small compared to our estimates of what it could or should be. The obvious question is, "*WHY?*". If companies can make a better quality product and reduce their quality losses by setting up a good quality control program, why haven't most companies gone all out?

A long list of reasons can be offered, but standing out sharply at the top is:

> *The failure to secure top management interest, understanding, appreciation and support and, or because of, the failure to plan a really practical quality control program which convincingly established the fact that every dollar spent on quality control would bring about a substantial return in the reduction of existing quality losses.*

The Mal-Distribution Principle

If we define **Quality Losses** as all the costs and losses which disappear if all quality problems were eliminated, we necessarily include Procurement, Design, Engineering, Manufacturing and all activities on through to sales and customer acceptance investigations. Better quality, then, is unavoidable if quality losses are reduced. We shall limit our discussion here to a program for the reduction of quality losses in manufacturing.

Experience indicates time and again that while most measured effects are actually cumulative effects of many causes, a small minority contribute to a major share of the total effect whereas the large majority of causes are responsible for a very small share of the total effect.

When all the losses due to sub-standard product in a manufacturing operation are broken down by products, we generally find that only a few out of many products are responsible for more than half the losses.

When all the variation in a product can be apportioned to each of the sources of variation, we find that a very few of the sources contribute most of the variation.

If all the scrap in a machine shop were studied by machine, we would generally find that a few of the many machines or one type of machine out of many types are responsible for most of the scrap loss.

The basic principle is essential in planning a QC program in which every dollar spent must account for several dollars of reduction in quality losses. We shall refer to it as the *principle of mal-distribution*. It clearly indicates that profit-making SQC activity cannot be spread over a whole manufacturing operation like a coat of paint, since quality losses are certainly not spread out that way. This mal-distribution can at times be so severe that as few as 10 percent of all the categories of quality losses may account for as much as 75 percent of the total loss. In one particular plastics film extrusion operation, one category of loss accounted for more than 50 percent of all the losses. An investment of QC dollars could—and did—bring a tremendous return.

If the mal-distribution principle seems at times to be out of operation in getting a distribution of the contributions to a particular effect, it may be that the best categories of breakdown have not been selected. For example, in an iron foundry, a breakdown of total scrap by types of defect indicated an almost equal contribution of scrap by each type of defect.

However, this was a job-shop type of operation involving short runs on several hundred different patterns, with about 100 patterns in each week. A breakdown by patterns showed that 15 percent of all patterns accounted for more than ⅔ of all the scrap. A QC program which succeeded in eliminating the one most prevalent type of defect could mean a total reduction in scrap loss which was less than the cost of achieving and maintaining this reduction. However, a QC program which succeeded in reducing the scrap for the one largest scrap-producing pattern each week could bring a substantially greater return. As a matter of fact, a QC program which placed its major emphasis on the 15

largest scrap-producing patterns each week and on keeping new patterns out of this category succeeded in reducing an average monthly scrap loss of $20,000 to approximately $13,000 in 4 months and to less than $10,000 in 8 months.

Charts previously kept on a large number of measurable operating conditions in sand and metal had been ineffective in accounting for scrap. Their cost was extremely difficult to justify. The QC program led to the fact that only a few of the many controlled operating variables were really important in affecting scrap, and tight control of these few could be maintained at considerably less cost than previously expended on all the operating variables. The mal-distribution principle was in operation. A substantial reduction in inspection hours and in finishing hours and the value of over-all improved quality were not included in the scrap loss figures.

Multi-Vari Charts

Having selected the areas for profitable investment of QC dollars, a systematic plan of action is necessary. Directly or indirectly, most quality losses are a result of variation in a particular quality characteristic of the product. This variation may manifest itself in an attribute "good or bad" property or in a measurable property which varies too much to remain within specified limits for acceptable product. We shall assume that the importance and validity of the specification and the ability to adequately measure the product against this specification have been established as a very important but nevertheless routine function of the QC system.

Since we recognize variation as a cumulative effect of all non-constant conditions in the manufacturing operation, we again seek to isolate the few non-constant conditions which we expect will account for most of the total variation. We are not particularly interested in noting whether these are assignable or unassignable causes of variation. We are interested only in identifying them as the major sources of variation. In other words if the process capability accounts for almost all the variation, we shall seek those conditions which most affect the process capability. If the process capability is a small part of the total variations, we shall look for factors which would normally be called assignable causes.

If repeated tests on the same piece of electronic equipment account for a large share of the variation, then causes of instability in the test method, the test gear, the test conditions, or in the equipment itself must be found.

In a processing operation, the minute-to-minute differences may be small but the hour-to-hour fluctuations may account for most of the product variation. Factors which can possibly change from hour-to-hour would be sought.

It is possible for us to estimate the portion of the total variation which is attributable to changes occurring within a unit or from unit-to-unit, or lot-to-lot of raw material, machine-to-machine, hour-to-hour, operator-to-operator, shift-to-shift, day-to-day, or any other reasonable category. Each manufacturing operation has categories which may be characteristics of itself. A foundry operation would add: cavity-to-cavity differences, cope-to-drag differences, mold-to-mold differences, batch-to-batch differences in sand, heat-to-heat differences in metal, etc.

Small samples, selected at the appropriate times and treated graphically will supply the information we want. A control chart procedure can be adapted for this purpose, but the multi-vari charts[1] are even simpler and more appropriate for this application.

In Fig. 1, five measurements on each of five consecutive pieces at every two-hour interval indicate alternative conditions.

The first shows large within unit variation as the major component of variation, the second shows time-to-time variation as the major component of variation, and the third shows unit-to-unit variation as the major contributor.

At this point, experience with the operation may be sufficient to identify the non-constant condition which explains the picture given by the multi-vari charts. A simple one-factor experiment with the suspect condition set at two or three levels will provide the objective evidence required. If two or three alternative conditions are strong suspects, their effects may simultaneously be evaluated by simple experimental designs. If the correct factor has been isolated, the experiment measures its effect quantitatively.

Random Balance Experiments

The control chart, the multi-vari chart, or some similar technique provides a systematic first step. Experience, horse sense, and simple designed experiments may sometimes suffice to finish the job. More often than not, however, the easily identifiable trouble sources have long since been isolated and kept in check. There may now be as many theories as there are variables; perhaps 15 to 20 of them including their interactions, which could explain the major category of variation identified in the multi-vari charts. The usual designed experiments fail us by becoming impracticably large and complex. Ten factors at two levels of each require 1024 test units, an impossible situation.

The recent development of the random balance experiment[2] by Frank Satterthwaite provides a major break-through by which the 20 factors may all be surveyed in as few as 30 test units. Underlying the successful application of random balance techniques, we again find under the mal-distribution principle, that only two, three, or four of the 20 factors under examination are responsible for a major share of the total variation.

In a chemical company, manufacturing a variety of plastic materials, the largest quality loss was attributable to one particular quality characteristic of one of the products. Multi-vari charts indicated that the greatest variation occurred from hour-to-hour. This could be explained by any of 12 operating parameters includ-

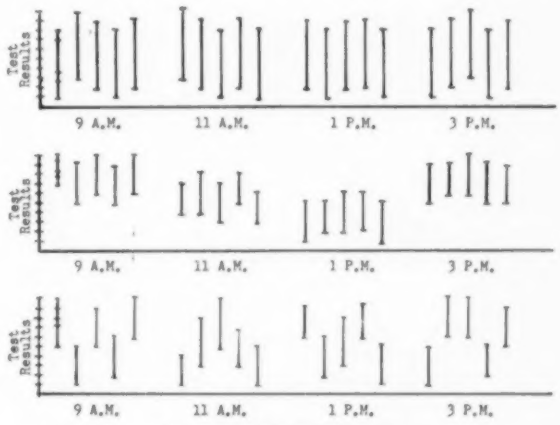

Figure 1—Multi-Vari Analysis

ing several temperatures, percentages of ingredients, speeds, etc. Six of the 12 were used by the operators to maintain control of the process. The recorded history of the 12 variables measured indicated their normal range of operating conditions. Each of the 12 was programmed into a random balance experiment of 30 test runs with the two levels of each set at the high and low values of their normal operating experience. The results showed that only two of the suspected six, along with one of the unsuspected six, were critical in their effect on the product. A considerable portion of the variation which still remained was finally explained by instability in the gages in the processing equipment. By maintaining rigid specifications of operating conditions for these three variables, improving instrumentation, setting-up well-defined rules for regular calibration, and the elimination of operator judgment in making adjustments, 10 percent quality losses on the product were reduced to 2 percent.

Briefly described, the random balance experiment requires the randomization of an equal number of each of the levels of each of the factors among the 30 runs (or other specified number of runs).

Referring to Table I, Variable I has 15 High levels and 15 Low levels in randomized order. Variable II has 10 High levels, 10 Medium levels and 10 Low levels in random order. Variable XX has 10 each of different lots A, B and C of one of the raw materials in random order.

The results are quickly surveyed in a series of scatter diagrams for each input variable against the measured output characteristic. (See Fig. 2.)

It is readily apparent that the difference between the High and the Low levels of Variable I contributes nothing to the total variation. The change from High to Medium to Low levels on Variable II make a definite contribution to the total variation and similarly for Variable III. Thus, less total variation is possible if Variables II and III are restricted within narrower operating limits.

The illustration shows the technique stripped down to its simplest elements. While it is somewhat more involved in design and in analysis, it is a basically simple and attractive approach which quickly gains the confidence of both management and operating level personnel.

One final step may be required in establishing the optimum operating conditions for identified critical variables. The Box technique of evolutionary operation[3] is a sufficiently simple approach which can be understood and appreciated by supervisory personnel. If two critical factors require optimization, small changes in these factors in series of 2 × 2 designed experiments will indicate the direction for optimum conditions until they are finally reached.

TABLE I—Specification of Test Conditions in Random Balance Experiment

Test No.	Variables									Test Results
	I	II	III	IV	•	•	•	•	XX	
1	H	M	H	L	•	•	•	•	C	52
2	L	H	L	L	•	•	•	•	A	36
3	L	L	L	M	•	•	•	•	C	53
4	H	H	L	L	•	•	•	•	B	57
5	L	H	H	L	•	•	•	•	B	24
6	H	M	H	H	•	•	•	•	A	44
7	L	M	L	H	•	•	•	•	B	17
8	L	L	H	M	•	•	•	•	B	37
9	L	L	H	H	•	•	•	•	A	26
10	H	M	L	M	•	•	•	•	A	61
11	L	H	H	L	•	•	•	•	C	37
12	L	L	H	L	•	•	•	•	C	34
13	H	M	H	M	•	•	•	•	B	41
14	H	M	H	M	•	•	•	•	B	21
15	H	L	L	H	•	•	•	•	C	77
•	•	•	•	•	•	•	•	•	•	
•	•	•	•	•	•	•	•	•	•	
•	•	•	•	•	•	•	•	•	•	
29	L	H	L	M	•	•	•	•	C	51
30	H	M	L	H	•	•	•	•	A	37

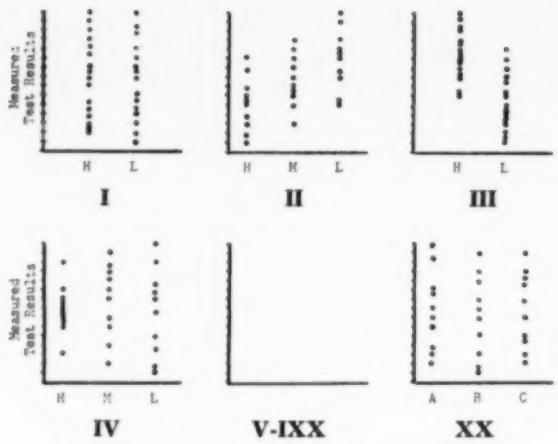

Figure 2—Test Results for Each Level of Each Variable

Summary

When the systematic activity has removed the largest source of quality loss and the second largest and so on down the line, a point must finally be reached at which the reduction of the next largest source of quality loss would no longer justify the expenditure of QC dollars. If the major causes contributing to quality losses, as uncovered, are placed under a reliable system of operating or process control, and if specifications on operating conditions are written or re-written to include the important discoveries, an economic quality level once attained can be maintained at relatively low QC costs.

A complete QC program, as mentioned above, must begin at the earliest conception of the product and follow through to the consumer. The science of quality control is sufficiently advanced to supply equally effective programs in every key quality area. QC losses on new products would be at a minimum if effective QC planning were brought in at the ground floor.

When the quality losses are high because of the absence of a complete and effective QC system, management will not disregard a program based on facts in dollars and cents, but will support one which makes sense as well as dollars.

This is the kind of program which must and can be sold to top management.

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The Quality Control Budget *in the Changing Electronics Industry*

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Editorial Note

This article deals with an admittedly controversial subject which is nevertheless of fundamental importance. We believe its presentation, as submitted by its author, together with the reviews given it by two independent referees familiar with quality control operations in the electronic industry, makes a contribution well worth the thoughtful attention of *Industrial Quality Control* readers. If this article and the discussions of it, succeed in stimulating constructive thinking, its major purpose will have been served.

M. E. W.

Does the Quality Control Budget Represent the True Cost?

The budget is the keystone of the quality control program. It is the vital link between the quality control organization and general management. The preparation of the budget, "selling" it to general management and keeping it sold is the quality control administrator's most important task.

For this reason the budget should be clear and explicit; it should reflect the situation exactly as it is today. The following is an examination of quality control practices in the electronics industry, in an effort to determine whether the true total cost of quality control is represented in the quality control budget.

Every quality control administrator knows what it is to prepare the budget and to find that he has a total far beyond the expectations of general management. As an example, there is a disposition to believe, in the electronics industry, that total quality control charges should not exceed 6 or 7 percent of the cost of manufacture. Yet this figure has generally been exceeded ever since Korea and is approaching 25 percent in the missile industry.

Increasing Demand for Quality Control

The emphatic demand for more quality control has been provoked by the increasing complexity of modern electronic products. The need for a degree of reliability far beyond any previous standard has increased the demand for adequate quality control to an agonized wail in the missile industry.

This increasing and insistent demand for more and more quality control, coupled with a sincerely motivated pressure against the corresponding rise in cost, creates a dilemma for the quality control administrator. Unless he looks carefully into the past and searchingly into the future, so that he gets a clear picture of the tremendous changes taking place in industry and the inevitable problems created thereby, he is liable to sink into frustration.

The resistance to the true current cost of quality control is not just another facet of the normal resistance to rising costs and expenses. It is more profound than that; it is more like a case of shock, and the causes must be understood by the quality control administrator if he is to assuage it sympathetically.

The Traditional Organization

The shock is caused by comparison with a traditional cost structure which has carried over from earlier days. There was a time when the main burden of the manufacturing effort rested on skilled manual labor. A small force of order writers, accountants and other sedentary workers was all that was necessary to support this basic group of producers. Since the skilled manual workers were so obviously productive, and the clerks and accountants clearly accessory, it was natural to label the one "productive" and the other "non-productive". This was a rather harsh distinction since it tended to characterize the clerks as parasitic, or free-loaders. However, it was in the spirit of the times, it was enshrined in accounting terminology and has been with us ever since. "Direct" and "indirect" have come into common use but they do not conceal the old disparaging distinction.

Furthermore, the number of sedentary workers was very small by comparison with the much larger number of skilled manual workers. This created a low ratio of non-productive/productive workers and this too became a part of the tradition.

"Non-productive" Becomes Productive

The development of modern machine tools and mass production techniques have drastically changed the relative strength of manual and sedentary groups and the latter now frequently outnumber the former. Engineers, production planning men, methods engineers, time study men and quality control engineers are responsible for the tremendously increased rate of production and they have become the true productive force.

These new groups were all labeled "indirect" and the traditional ratios of indirect to direct labor were far exceeded. The old accounting terminology did not change

because of the indisputable soundness of its basic intention which was keeping expenses relative to production costs low.

There were creaks and groans from the body industrial as the new sedentary groups grew in response to the inherent necessity and the accountants, worried by rising non-productive costs, restricted the budget. The accountants failed to see that the label no longer applied and the new men were too busy to recognize the importance of a label. It may be true in the world of poetry and romance that "a rose by any other name would smell as sweet," but this is not the case in industry.

It took the realistic stresses of World War II and the post-Korean rearmament to compel recognition of the true character of the work of some of these sedentary production groups and they have received the coveted label "direct." Outstanding among these are the engineers and draftsmen who were first classified "direct" during World War II and have continued to have more and more of their various activities included in this classification.

Research and Development

One of the most remarkable differences between this present moment and the recent past is the relatively large sums of money willingly spent on engineering research and development. The proportion of money budgeted for research and development in many modern plants would have brought a normal decent citizen of the Thirties to the verge of apoplexy. Even as recently as 1950 the same citizen would have turned livid.

Quality Control and Inspection

Quality control has not yet received this recognition. There is an additional reason for this, over and above the fact that it bears the label "indirect." The statistical quality control techniques developed by Walter Shewhart were put into the hands of inspectors for their first industrial applications. At that time, the late Twenties and early Thirties, inspection was thought of as no more than a sorting operation, and its best recognized activity was the rejection of material. Although the material was defective, there were moments in the stress of production when its rejection appeared to be not merely non-productive, but anti-productive.

Thus, quality control was non-productive by definition and anti-productive by association. No quality control administrator should forget this recent historical background when confronted by the point of view which was its logical product.

Quality Control—A Production Technique

Time has demonstrated that statistical quality control is essentially a production technique aimed at preventing the manufacture of defective parts. Even so, the stigma attaching to the name and the association has resulted in a tendency to leave various quality control activities scattered around under more acceptable departmental labels.

It is for this reason that general management is rarely confronted with the true total cost of quality control. The problem is a product of the changing times and not of individual wishes and desires. The electronics industry is changing the most rapidly; it is a symbol of the times; it is the transition industry *par excellence*. A study of quality control in the electronics industry will best exemplify the problem. It will reveal the dismembered condition of quality control. A better word would be "unmembered" because the real situation is not that quality control has been taken apart, but that it has not been put together.

Quality Control Engineering

Quality control is first and foremost a critical function, creatively applied. Its first element is the quality control engineering and planning group. This is the group which plans the application of the statistical techniques at selected points in the manufacturing cycle. It might be thought that the very name of the group would save it from absorption in other activities. Yet even this prime element in quality control is sometimes found in Engineering, or in Industrial Engineering, or in Management Engineering under the guise of "statistical services." In this event the most outstanding characteristic of quality control activities will be concealed in the budget of another department.

Inspection and Test

If Quality Control Engineering and Planning is free and clear and properly recognized, it will require an organization with which to implement its plans. This means inspectors and testers. These together now make a relatively large body of men and women because electronic assemblies have become more difficult to inspect and test, while such new techniques as printed circuitry have simplified fabrication and assembly. The relative increase in the size of this group has been concealed to some extent by the custom of differentiating between inspectors and testers.

During World War II electronic testers were first labeled "direct" and the practice is now common. Inspectors, that is those who perform dimensional and visual inspections, have remained in the "non-productive" classification. Thus, inspectors are classified "indirect" and testers "direct," although they both perform a critical function and are essential parts of quality control. The testers, therefore, are sometimes included in the production direct labor budget, and a large and necessary quality control cost does not appear in the nominal quality control budget. Even the inspectors are sometimes broken up into a group under Production, probably called "production checkers," and a second group intended to check the work of the first group on a sampling basis. The second group may retain the title "inspectors" or they may be called quality control checkers, or possibly quality auditors. The production checkers become a part of a production budget and do not appear on the quality control budget. Whatever the label and distribution the function remains the same and these will all have to be included in one budget if we are to get the true cost of quality control.

Receiving Inspection

There is another group of inspectors engaged on the inspection of purchased materal in Receiving Inspection. This relatively isolated group is usually found under its own name. It is most intimately connected with Purchasing and Purchasing has not chosen to burden its budget with the cost of inspecting the material it buys. Receiving inspection will commonly be counted a part of the quality control cost.

Source Inspection

Source inspection, vendor quality control or vendor-vendee relations are various names for the excellent practice of making sure your supplier is producing good

material before it is delivered to your plant. It is more likely that this particular function will appear as a part of the Purchasing budget, but it is a strictly critical activity and becomes creatively critical when inspection procedures are worked out mutually helpful to buyer and seller. This is another part of the true cost of quality control wherever it may be found in the budget.

Gage Control

Gage control, the constant checking of the accuracy of the gages used by Inspection, and the periodic calibration of the instruments used by the testers are essential activities for the support of quality control. Gage control may be found in the Factory Maintenance budget and the instrument calibration service is sometimes found in the Engineering budget, but they remain parts of the true cost of quality control.

Test Engineering

An increasingly large job in modern electronic factories is the development of test specifications from the engineering design specification, and the design, construction and maintenance of production test equipment. Experience is demonstrating that there is much to be gained by having this activity directly answerable to Quality Control, where it will receive the proper priority and will be directed by a production-conscious group. The situation is fluid at the moment but the trend is towards putting this essential support for the critical function of testing under Quality Control.

Environmental Testing

Environmental testing of randomly chosen units from production on an agreed sampling plan is becoming increasingly necessary as electronic products become more and more complex, and as airborne electronics, traveling at supersonic speeds, demand degrees of reliability far beyond anything yet attempted. This is a quality control function but the work is still largely done in Engineering and its cost appears on the Engineering budget.

Conclusion

The electronics industry is expanding at a fantastic rate, new applications of its products are constantly being made, and its products are paramount in supersonic aviation. The many quality control activities have sprung into being only in response to the inherent demands of this situation. Wherever these activities are found they are being conscientiously pursued. Nevertheless, it cannot be doubted that quality control will substantially improve its present effectiveness and achieve its maximum economy of operation only when these various activities are united into one comprehensive group and under one budget.

. . . Discussion by David A. Hill, Hughes Aircraft Company

The first half (or so) of this article gives an excellent statement on a very real problem in the electronics industry. The rapid increase on industrial and military use of electronics makes it imperative that the enormously complex systems operate more reliably in service use. For the time being an increased quality control effort has been essential. It is not at all clear that the long range solution to the problem lies down this road. Radical improvements in parts design and assembly techniques are over the horizon. These hold the promise of greatly reducing the quality control burden.

Squires' article states at the beginning that the size of the quality control budget frightens management. At the end of the article he proposes to add to that budget a number of expensive functions. Is this a wise move? I am not certain that test engineering has to be under quality control. Having managed some programs where this was the case and others where it was not, I find it entirely possible to see that the quality control department gets first rate test equipment by making sure that test engineers are skilled in and make use of the quality control approach. We have also had increased success in persuading design engineers to learn and use statistical methods in developing new equipment. This can be more effective than trying to centralize statistical know-how in a group of specialists. There is one other point. While it is true that electronic testers are generally included in the "direct" expense budget, this does not prevent many companies from including them in quality control budgets.

Instead of emphasizing the admittedly touchy subject of quality control budgets, a more constructive approach seems to be a thorough study of the real cost of quality for a given product. W. J. Massers' article* presented some interesting ideas on this subject. We have set out to explore them further.

I sometimes find myself differing with colleagues in ASQC who seem convinced that the cure to industrial problems lies in giving Quality Control (speaking of it now as a department name) a wider and a wider scope of authority. It is my contention that a smart quality engineer is like a good doctor—always trying to put himself out of business (although in small danger of succeeding). In those cases at Hughes where we have been able to rack up a real success, it was generally because some development engineer, or purchasing agent or production superintendent came to understand the quality control approach and put his back into supporting it.

. . . Discussion by August B. Mundel, Sonotone Corporation

As usual, Frank Squires' article is interesting, well written, and entertaining.

The difference in definition of productive and non-productive labor is extremely variable industrially and is generally the result of a lack of true understanding of the industrial process. We, too, have had difficulties with this terminology, particularly in operations which were automatized or multiplexed, thereby markedly cutting down on the "direct" while leaving the overhead figures unchanged. Despite the fantastic increase in the percent of overhead, the cost fell markedly. Government auditors were most unhappy with the overhead rate on this operation and tried hard to disallow this as part of the cost. Squires' article clearly points out this fallacy and also the methods used to bury the quality control costs. An important contribution is made by actually quoting the percentage for the quality control function, or at least that part of the function which was recognized as quality control. This is the first place I recall seeing a specific figure quoted.

Squires protests too much in referring to research and development costs and the efforts made to bury the quality control budget. Actually, even the quality control man helps bury the overhead costs when he calls a 100 percent inspection productive labor. The factory, we all know, needs a janitor and a service man just as much as it needs an operator. These essential service

*W. J. Masser, "The Quality Manager and Quality Costs," *Industrial Quality Control* Vol. XIV, No. 4, Oct. 1957, p. 5.

people never touch the product. We need them even though they are "non-productive."

The quoting of percentages of total labor used for quality control purposes is good in that it does create some knowledge of the work in other industries. There can never be an accurate knowledge of the work occurring elsewhere since the procedure in every plant is different. Therefore, this bench mark is not accurately defined and is dangerous in that it creates a false and misleading bench mark for others. Still the good outweighs the bad.

Promoting quality control does take salesmanship. An effective sales point on any service is "Does the service cost more than it saves or vice versa?" Some of us have been able to prove that the quality control operation has been an effective profit maker. We, therefore, get our budgets approved but, as people whose daily effort results in the criticism of the work of others, we can hardly complain when still others criticize us. Perhaps it is not the criticism *per se* that annoys Squires but the sort of criticism that is offered by those who seem totally unaware of the contributions and values of service. This type of individual we might expect to criticize a jeweler for making jewelry out of such expensive materials as silver, gold, or platinum. Think of the saving that could be achieved by using a base metal. Squires' article might be toned down slightly insofar as decrying criticism. Let us start contributing to the general knowledge of what control operations actually cost so that we may constructively assay our own operating efficiency and point out, as does Squires, what our expenditures are and where our hidden budget items are.

Determination of Optimum Operating Conditions by Experimental Methods

Part II-1 Models and Methods

J. STUART HUNTER

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Editorial Note

This is the first of three installments of the article that forms Part II of the series "Determination of Optimum Operating Conditions by Experimental Designs" that began with the Part I article by Ralph A. Bradley on "Mathematics and Statistics Fundamental to the Fitting of Response Surfaces" in the July 1958 issue of *Industrial Quality Control.*

One Dimensional Experimental Models

Oftentimes an experimenter is interested in exploring the relationship between some continuous response η as a function of some single quantitative variable x, the variable x being under the control of the experimenter. For example the response η might be the yield of some chemical process and the controlled variable x the length of time of the chemical reaction. Such studies, requiring the control of but a single variable, give rise to what can be termed "one dimensional" experimental designs.

Initially nothing may be known about the nature of the relationship; the variable η being simply an unknown function of x, i.e.,

$$\eta = f(x) \tag{1}$$

As a first step in exploring this association between η and x it is frequently assumed that the response η is a simple straight line function of x. The mathematical model expressing this linear relationship can be written as

$$\eta = \beta_0 + \beta x \tag{2}$$

where β_0 is the intercept of the line and β is the slope of the line. The choice of this model may be based on the results of analogous experimental studies, the knowledge that quite complicated functions can be illustrated by straight lines over limited ranges, or simply a first guess as to the nature of the response function, a guess to be improved upon, if necessary, as experimentation continues. A series of experiments may now be performed at different settings of the controlled variable x and at each of these settings one or more observations y recorded. Of course the observed value of the response y will never equal exactly the true value of the response η at any setting of x, in fact

$$y = \eta + \varepsilon \tag{3}$$

where ε is the error made in observing η. The mathematical model then becomes

$$y = \beta_0 + \beta x + \varepsilon \tag{4}$$

This linear relationship, where the exponent of the controlled variable x is unity, is called a "First Order" mathematical model. Estimates of the coefficients β_0 and β can now be quickly obtained using least squares.

Least Squares Estimates

In the following example, the least squares estimates of β_0 and of β will be obtained using the computational technique described in most standard statistical texts. The example will then be repeated using another computational format of more general applicability.

Suppose that at each setting of the controlled variable x_i an observation y_i is recorded ($i = 1, 2, \ldots, N$). For example, suppose that the following set of data are obtained and that it is the decision of the experimenter to fit the first order model $y = \beta_0 + \beta x + \varepsilon$. We then have

*Presently with the Statistical Techniques Research Group, Princeton University.

Controlled Variable	*Response Variable*
x	y
2	8
3	7
4	5
5	3
6	1

The least squares estimates of the coefficients β_0 and β are obtained from the following familiar formulas:

The estimate of β

$$b = \frac{\Sigma x_i y_i - (\Sigma x_i)(\Sigma y_i)/N}{\Sigma x_i^2 - (\Sigma x_i)^2/N} = \frac{Sxy}{Sx^2} \qquad (5)$$

that is,

$$b = \frac{78 - 20(24)/5}{90 - 20(20)/5} = \frac{-18}{10} = -1.8$$

The estimate of β_0

$$b_0 = \frac{\Sigma y_i}{N} - b\left(\frac{\Sigma x_i}{N}\right) = \bar{y} - b\bar{x} \qquad (6)$$

where $\bar{y}$ and $\bar{x}$ are the averages of the y's and x's. Thus,

$$b_0 = \frac{24}{5} - (-1.8)\left(\frac{20}{5}\right) = 12.0$$

(Unless noted otherwise the summation sign Σ will always indicate the summation of all quantities with an i subscript as i goes from 1 to N.)

In the equation for b the terms Sxy and Sx^2 are frequently called the "Corrected Sum of Cross-products" and "Corrected Sum of Squares" of the xy and the x's respectively. The term $Sy^2 = \Sigma y^2 - (\Sigma y)^2/N$ would be, similarly, the "Corrected Sum of Squares" of the y's.

The fitted equation is therefore

$$\hat{y} = 12.0 - 1.8x$$

where $\hat{y}$ stands for the predicted value of y at any chosen setting of x. This least squares fitted equation guarantees that the sum of squares of the residuals (predicted responses − observed responses) is a minimum; i.e., that

$$\Sigma(\hat{y}_i - y_i)^2$$

is a minimum. The predicted values of the response calculated from the fitted equation are:

Controlled Variable	*Predicted Responses*	*Observed Response*	*Residuals*	
x	$\hat{y}$	y	$(\hat{y}-y)$	$(\hat{y}-y)^2$
2	8.4	8.0	0.4	0.16
3	6.6	7.0	−0.4	0.16
4	4.8	5.0	−0.2	0.04
5	3.0	3.0	0	0
6	1.2	1.0	0.2	0.04

We observe now that $\Sigma(\hat{y}-y)$ equals zero, and that $\Sigma(\hat{y}-y)^2 = 0.40$.

Errors of Observation

Up to this point nothing has been said about the nature of the errors made in measuring the true response η. In estimating the coefficients in this mathematical model nothing need be said concerning these errors, the least squares procedure being a completely algebraic manipulation guaranteeing that $\Sigma(\hat{y}-y)^2$ is a minimum. Let us assume now that these errors are random, independent events from a Normal distribution having a mean equal to zero and a variance independent of x, everywhere constant, and equal to σ^2. Let us assume further that the failure of the fitted mathematical model to fit the observations exactly is a function solely of these errors. (As will be indicated later, this last assumption is hazardous.) Granting these two assumptions, the term $\Sigma(\hat{y}-y)^2$ divided by its "degrees of freedom" (the total number of observations minus the number of constants estimated) provides an unbiased estimate of the error variance σ^2, thus

$$s^2 = \text{the estimate of the error variance} = \frac{\Sigma(y_i - \hat{y}_i)^2}{N - k} \qquad (8)$$

where

k = the number of constants estimated in the model.

(As will be noted later, this estimate of variance can be seriously inflated if an "inadequate" mathematical model has been chosen.) Assuming in this example that the straight line model proposed will adequately represent the data, the estimate of variance becomes

$$s^2 = \frac{0.40}{3} = 0.1333$$

Knowing this variance of the individual observations, we can calculate the variance of statistics estimated from the observations. For example, it is well known that the variance of an average calculated from N observations is σ^2/N, and that this quantity is estimated by s^2/N.

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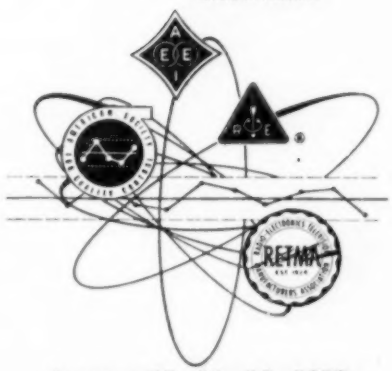

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Similarly, the estimated variance of the statistic b is given by

$$\text{Estimated variance of } b = \frac{s^2}{Sx^2} = s_b^2 \qquad (9)$$

Thus in our example

$$s_b^2 = \frac{0.1333}{10} = 0.0133$$

The t and F Statistics

Having now estimated the variance of b we can, using the t statistic, establish a confidence interval about b or perform a test of significance.

The 95 percent confidence interval about the estimated slope is given by

$$b \pm t_\alpha \sqrt{s_b^2} = -1.8 \pm 3.182 \sqrt{0.0133} \qquad (10)$$

$$\text{or } -2.2 \leq \beta \leq -1.4$$

where t_α is a constant, drawn from the t tables with $(N-k)$ degrees of freedom to provide a $(1-\alpha)$ percent confidence interval. The value of $t = 3.182$ was selected from the t tables with 3 degrees of freedom at the $\alpha = 0.05$ probability level. The number of degrees of freedom for t equals the number of degrees of freedom entering the estimate of variance.

One meaningful way to view the interval $-2.2 \leq \beta \leq -1.4$ is to reject as implausible all postulated values of β which lie outside the interval and to take the viewpoint that all postulated values of β lying within the interval are not contradicted by the data at the level of probability indicated.

To determine whether the estimated slope, $b = -1.80$, is "significantly" different from zero, we calculate the t statistic

$$t = \frac{(b - \beta)}{\sqrt{s_b^2}} = \frac{-1.80 - 0}{\sqrt{0.0133}} = -15.6 \qquad (11)$$

where β, the hypothesized true value, is set equal to zero. To be significant at the 95 percent level the absolute value of t must be greater than 3.182. Since the calculated value of t does exceed this quantity, we can declare that the test is significant, i.e. that β is not equal to zero and hence that a relationship associating y as a linear function of x has been demonstrated.

This test of significance can also be performed by constructing an Analysis of Variance Table as follows:

	Sum of Squares	*Degrees of Freedom*	*Mean Square*	*F Ratios*
Total Crude Sum of Squares $= \Sigma y_i^2$	148.0	5		
Sum of Squares absorbed by b_o $= \frac{(\Sigma y_i)^2}{N}$	115.2	1		
Sum of Squares absorbed by b $= bSxy$	32.4	1	32.400	$F_{1,3} = 243$
Residual Sum of Squares (by subtraction):	0.4	$(N-k)=3$	$s^2=0.1333$	

The sum of squares absorbed by b_o is often called the "Correction Factor" or the "Correction for the Mean".

As a check on the calculations we note that the residual sum of squares in the Analysis of Variance Table is equal to $\Sigma(\hat{y}-y)^2 = 0.40$.

Now, granting that the failure of the fitted model to account exactly for the observations is a function solely of errors which are independent and Normally distributed with constant variance (only the assumptions concerning the model and the independence of the errors are really crucial), then the residual sum of squares divided by its degrees of freedom, sometimes called error mean square, provides a valid estimate of σ^2, the error variance. Furthermore, under the hypothesis that $\beta = 0$, the sum of squares absorbed by b divided by its single degree of freedom, sometimes called the mean square for b, also provides a valid estimate of σ^2. The ratio of these two estimates of variance, i.e. the F statistic with 1 and 3 degrees of freedom in this example, can now be used to determine the probability of obtaining these two estimates, granting the hypothesis is true. In this example we obtain

$$F_{1,3} = \frac{\text{Mean Square for b}}{\text{Error Mean Square}} = \frac{32.4000}{0.1333} \qquad (12)$$

$$= 243^{***} \text{ Highly Significant}$$

Looking up the value of the F statistic with 1 and 3 degrees of freedom (the degrees of freedom associated with the numerator and denominator mean squares) we find that if the hypothesis $\beta = 0$ is true, the probability of observing this value of F is very small, in fact less than 1 in 1000. We decide therefore to reject the hypothesis that $\beta = 0$, and as a consequence once again conclude that a relationship associating y as a linear function of x has been demonstrated.

An interesting check is possible here between the tests of significance determined by the t statistic and the F statistic. The calculated value of t with 3 degrees of freedom is $t = 15.6$, and the calculated value of $F_{1,3} = 243$. Whenever the number of degrees of freedom in the numerator of the F test equals unity, then $F = t^2$.

The Forward Doolittle Technique for Estimating Coefficients

Although the formulas for obtaining the estimates b and b_o given above are convenient to use, an alternative technique of calculation will now be described which provides both the estimates of the coefficients and the Analysis of Variance Table. This alternative method of calculation, called the *Forward Doolittle Technique* for solving normal equations, is also easily extended to mathematical models of considerably greater complexity, and is essential to a proper understanding of all that follows. However only a very brief description of the Forward Doolittle Technique is included here. This particular method of numerical analysis has been very well described in the article by Miss B. B. Day and colleagues, entitled "The Technique of Regression Analysis," *Industrial Quality Control*, Vol. XII, No. 2, August 1955, and again in the article by C. Kramer on "Simplified Computations of Multiple Regression," *Industrial Quality Control*, Vol. XIII, No. 8, February 1957. Another excellent description by Messrs. R. J. Hader and A. H. E. Grandage appears in the text *"Experimental Designs in Industry,"* Victor Chew, Editor; John Wiley & Sons, Inc., 1958. It should also be noted that this particular method of estimating coefficients is not unique or "best". Another technique called the "square root" method for doing these calculations is described in *"The Design and Analysis of*

Industrial Experiments," O. L. Davies, Editor, Hafner Publishers, New York, 1956; and again in the text "*Linear Computations*" by P. S. Dwyer, John Wiley & Sons, Inc., New York, 1951

For simple polynomial models such as those discussed in this section, using the Doolittle technique for solving the normal equations may appear to many readers to be the most cumbersome way to do what are well known to be simple calculations. However, these techniques are valid whatever the number of coefficients to be estimated in a polynomial model. For this reason, the technique is used in this article for both the simple and more involved models.

Beginning anew with the same data given above we wish to fit the following mathematical model

$$y = \beta_0 x_0 + \beta x + \varepsilon \qquad (13)$$

The new variable x_0 which appears above is a "dummy" variable and is always equal to unity. We now write down the following array of observations with the associated array of controlled variables.

	Observation Vector		*Matrix of Independent Variables*	
	y		x_0	x
$\underline{Y} =$	8.0	$X =$	1	2
	7.0		1	3
	5.0		1	4
	3.0		1	5
	1.0		1	6

In mathematical parlance the array of observations Y is often called the "Vector of Observations" and the associated array $\underline{X}$ the "Matrix of Independent Variables". It will be recalled that in obtaining the least squares estimates of β and β_0 the terms Σx, Σy, Σx^2 and N = the number of observations, were required. We begin then to organize the calculations by constructing Table 1 and Table 2.

Table 1

N	Σx	Σy
	Σx^2	Σxy

Table 2

5	20	24
	90	78

Table 3

A_{11}	A_{12}	A_{13}
	A_{22}	A_{23}

The sequence of operations which now follow may appear unduly cumbersome at first, but if performed a few times, a certain symmetry of form will be recognized and the method becomes quite automatic. To facilitate an understanding of the method the example will be illustrated using the numerical data from Table 2, and with the letters A_{ij} given in Table 3 (i gives the row number, j the column).

First, copy down the first row under the given table and divide all the elements in this row by the leading element, thus

5	20	24	A_{11}	A_{12}	A_{13}
	90	78		A_{22}	A_{23}
5	20	24	A_{11}	A_{12}	A_{13}
1	4.0	4.8	1	a_2	a_3

Next, using the element a_2 as a "pivot", take the product of $(a_2)(A_{12})$ from A_{22} and record the result. Repeat with $(a_2)(A_{13})$ from A_{23} thus

	5	20	24	A_{11}	A_{12}	A_{13}
		90	78		A_{22}	A_{23}
	5	20	24	A_{11}	A_{12}	A_{13}
Equation for b_0:	1	4.0	4.8	1	a_2	a_3
		10.0	−18.0	$(A_{12}-a_2A_{12})$	$(A_{23}-a_2A_{13})$	= d
Equation for b:		1	− 1.8	1	$\frac{(A_{23}-a_2A_{13})}{(A_{22}-a_2A_{12})}$	= e

Once again, divide through by the leading element. The estimate of the coefficient β is given in the last line of the table. In fact this line may be read as

$$(1)b = -1.8$$

Similarly the estimate of the intercept β_0 is given by the last line of the first pair of lines which may be read as

$$(1)b_0 + (4.0)b = 4.8$$

Thus

$$b_0 = 12.0$$

As before the fitted equation is

$$\hat{y} = 12.0 - 1.8x$$

Thirteenth Midwest Quality Control Conference

Fifteen technical sessions plus a two day training course in SQC comprised the Thirteenth Midwest QC Conference which was held Nov. 6-7 at the Hotel Muehlebach in Kansas City, Mo.

Highlights of the conference included a discussion of sampling methods by Prof. Harold F. Dodge and a missile reliability symposium. The symposium was composed of Dr. James A. Van Allen, University of Iowa satellite scientist, and James M. Bridges, director of electronics, Office of the Assistant Secretary of Defense. Dr. Lloyd Knowler, head of the department of mathematics and astronomy at the University of Iowa, was moderator.

Society President C. E. Fisher is presented with the "Key to Kansas City" by Mayor H. Roe Bartle. Looking on is Dr. Frank A. Barta, general chairman of the Thirteenth Midwest Conference.

The Grand Ballroom of the Hotel Muehlebach was the "battleground" where verbal SQC and QC "weapons" were used to conquer groups such as the one shown above.

The Analysis of Variance Table is quickly constructed. The sum of squares associated with the estimate b_0 is given by the product of $(a_3)(A_{13})$, i.e. $(4.8)(24)$. The sum of squares associated with the estimate b is given by $(d)(e)$, i.e. $(-18.0)(-1.8)$. Thus

Analysis of Variance Table

			ss	*df*	*ms*
Crude Sum of Squares =	Σy^2	=	148.0	5	
Sum of Squares for b_0 =	$(24)(4.8)$	=	115.2	1	
Sum of Squares for b =	$(-18)(-1.8)$	=	32.4	1	32.4
Residual Sum of Squares			0.4	3	0.1333

As an exercise it is easy to show that this technique when used on Table 1 gives the formulas for b and b_0.

This second method for determining the estimates of the coefficients in a regression model is called the "Forward Doolittle Solution" of the "Normal Equations" generated by the least squares procedure. As noted in R. A. Bradley's article "Determination of Optimum Operating Conditions by Experimental Methods, Part I, *Industrial Quality Control*, Vol. XV, No. 1, July 1958, a complete analysis of the data requires that the "inverse" of the coefficient matrix of the normal equations be calculated. The diagonal elements of this inverse matrix when multiplied by the estimate of variance, give the estimated variance of the coefficients, i.e. s_b^2. The variances of the coefficients are required for the calculation of confidence intervals. These important steps in a thorough regression analysis are not described here, and the reader is referred to Dr. Bradley's article.

Measures of Experimental Error and Lack of Fit

In a study of the effect of temperature upon the creation of impurities in a chemical batch process an experiment was run at each of five different temperatures. The results of this experimental program are illustrated in Fig. 1.

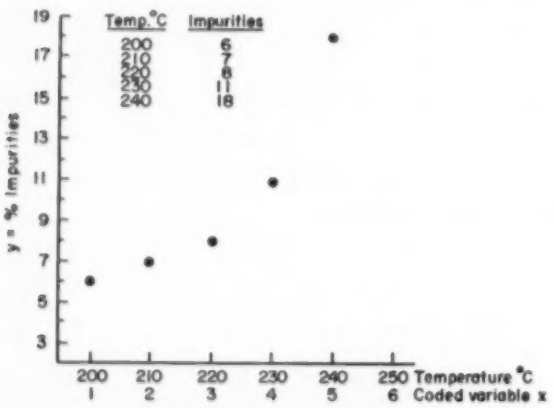

Figure 1

It was then proposed that a straight line, i.e. a first order mathematical model, be fitted to these data associating the percent impurities as the response to temperature as the controlled variable.

Before beginning any calculation, however, it is advantageous to code the levels of temperature so that the numbers appearing in the normal equations are not unduly unbalanced in size. For this immediate problem the following coding mechanism is used.

$$\text{Let } x = \frac{\text{Temperature} - 190}{10}$$

Ideally a coding mechanism should be used which will force $\Sigma x = 0$ and $\Sigma x^2 = N$ where N is the total number of observations. The levels of x are recorded on the graph along with their associated temperature levels. The problem now is to fit the first order model $y = \beta_0 x_0 + \beta_1 x + \varepsilon$ to the observed data. The vector of observations and associated matrix of independent variables are

Vector of Observations *Matrix of Independent Variables*

$$Y = \begin{bmatrix} 6 \\ 7 \\ 8 \\ 11 \\ 18 \end{bmatrix} \qquad \underline{X} = \begin{bmatrix} x_0 & x \\ 1 & 1 \\ 1 & 2 \\ 1 & 3 \\ 1 & 4 \\ 1 & 5 \end{bmatrix}$$

Setting up the Doolittle solution gives

N	Σx	Σy	5	15	50
	Σx^2	Σxy		55	178
			5	15	50
			1	3	10
				10	28
				1	2.8

From the last line above

$$(1)b = 2.8$$

and from line 4

$$(1)b_0 + (3)b = 10$$

$$b_0 = 1.6$$

Thus

$$\hat{y} = 1.6 + 2.8x$$

Decoding the variable x to temperature gives

$$\hat{y} = 1.6 + 2.8\left(\frac{T-190}{10}\right) = -51.6 + 0.28T$$

The Analysis of Variance Table is

	ss	*df*	*ms*	
Σy^2	594.0	5		
Sum of Squares due to b_0	500.0	1		
Sum of Squares due to b	78.4	1	78.4	$F_{1,3} = 15.0^*$
Residual Sum of Squares	15.6	3	5.2	

*Significant at the 5 percent level.

It is of real importance now to look more closely at the residual sum of squares $= \Sigma\,(\hat{y}-y)^2 = 15.6$. Suppose that the *true* relationship between percent impurities and temperature *is* a straight line. Then the failure of the observed values to lie directly along this straight line must be a function of the experimental errors. A measure of these errors is provided by the differences between the observed values y and the predicted values $\hat{y}$ found along the fitted straight line. The sum of squares of these differences, $\Sigma(\hat{y}-y)^2$ is given in the residual sum of squares. This quantity divided by its associated degrees of freedom provides a valid estimate of σ^2, the variance of the errors of measurement. In the example the estimate of the variance of the observations equals

5.2, and the resultant estimate of the standard deviation of the observations is $\sqrt{5.2} = 2.3$ percent.

The hypothesis $\beta = 0$ can now be tested using the F statistic as shown in the above table. The calculated F ratio is significant, that is, the probability $F_{1,3} \geq 15.0$ is less than 0.05. Thus the hypothesis that $\beta = 0$ is rejected and as a consequence the fitted straight line is accepted as a meaningful explanation of the data.

Suppose, however, the true relationship between percent impurities and temperature is *not* a straight line. The differences between the responses predicted by the straight line $\hat{y}$ and the observed values y would now be the result of two factors: the experimental error and the *selection of an inadequate mathematical model.* A quick glance at the data in the example suggests that some form of curved line, a parabola or perhaps an exponential curve, might do a much better job of modeling the relationship than the proposed straight line.

The important question now arises: "How can one tell whether the failure of the predicted values $\hat{y}$ to equal the observed values y is a function of experimental errors alone or a function of experimental errors and an inappropriate mathematical model?" Before this question can be answered it is necessary to:

1. Take observations at enough different settings of the controlled variable so that one cannot fit the data exactly (for example, at least three points for a straight line), and
2. Obtain an estimate of experimental error that is independent of the proposed mathematical model. Independent estimates of experimental error can be obtained by repeating experiments.

For example, suppose that 12 experiments were run in some random sequence in the chemical batch process described above and that when the program was completed three observations were taken when $x = 1$, and again when $x = 5$, and two observations each when $x = 2, 3, 4$. Fitting a first order model as before gives

$$y = \beta_0 x_0 + \beta x + \varepsilon$$

Vector of Observations	*Matrix of Independent Variables*	
y	x_0	x_1
6.4	1	1
5.6	1	1
6.0	1	1
7.5	1	2
6.5	1	2
8.3	1	3
7.7	1	3
11.7	1	4
10.3	1	4
17.6	1	5
18.0	1	5
18.4	1	5

N	Σx	Σy
	Σx^2	Σxy
12	36	124.0
	136	452.0
12	36	124.0
1	3	10.3333
	28	80.0
	1	2.8571

$$(1)\,b = 2.86$$

$$(1)\,b_0 + (3)\,b = 10.33$$

$$b_0 = 1.76$$

Thus $\hat{y} = 1.76 + 2.86x$

The Analysis of Variance Table is

	ss	*df*	m_x	
Σy^2	1550.3000	12		
Due to b_0: (the correction factor 124 × 10.3333)	1281.3329	1		
Due to b: (d × e = 80 × 2.8571)	228.5680	1		
Residual	40.3991	10	4.0399	
Lack of Fit (by subtraction)	38.0991	3	12.6997	$F_{3,7} = 38^{**}$
Experimental Error	2.3000	7	0.3286	

**Significant at the one percent level.

The important change in this Analysis of Variance Table is the inclusion of a Lack of Fit Sum of Squares and an Experimental Error Sum of Squares.

A valid estimate of the error variance in this example is provided by the replicated trials at each setting of x. Under the assumption that the error variance is unaffected by x, an estimate of σ^2 is calculated by pooling estimates of variance made at each setting. This operation can be shortened by calculating the within corrected sum of squares of the observations, that is the quantities $Sy^2 = (\Sigma y^2 - \frac{(\Sigma y)^2}{n})$ at each setting of x, adding these corrected sums of squares together, and

Meet the new Saddoris Award Chairman

William A. Golomski

The new chairman of the Saddoris Award Committee is William A. Golomski, Manager, Operations Research, Oscar Mayer & Co., Madison, Wisconsin.

Mr. Golomski has an impressive educational background to aid him in his important position within the Society. It includes: Wisconsin State College, Marquette University, St. Louis University, University of Chicago, and The Virginia Polytechnic Institute. In addition, he has taught at Wisconsin State College, Marquette University, St. Louis University, and the University of Wisconsin.

Bill is a past president of the Milwaukee chapter of ASA, a past chairman of the Milwaukee section of ASQC, president of the Wisconsin Mathematics Council, and holds membership in other professional, social, and civic organizations.

Here's a message from Bill: "I encourage all members of the Society to send me their suggestions for the improvement of the Saddoris Award program."

then dividing this total by the sum of their accumulated degrees of freedom. Thus

At x = 1			At x = 5		
y = 6.4; 5.6; 6.0			y = 17.6; 18.0; 18.4		
	ss	*df*		*ss*	*df*
Σy^2 =	108.32	3	Σy^2 =	972.32	3
CF =	108.00	1	CF =	972.00	1
Within =	0.32	2	Within =	0.32	2

Since only pairs of observations exist at the points x = 2, 3 and 4, the pooled error sum of squares is given by the more convenient formula

$$\frac{\Sigma(\text{differences})^2}{2} = \frac{(1.0)^2 + (0.6)^2 + (1.4)^2}{2} = \frac{3.32}{2} = 1.66$$

Thus the total pooled error sum of squares equals 1.66 + 0.32 + 0.32 = 2.30. The total pooled degrees of freedom equals seven. This sum of squares and its associated degrees of freedom are recorded in the Analysis of Variance Table and give an experimental error mean square of 0.3286, i.e. the pooled estimate of error variance is $s^2 = 0.3286$.

Now the *residual* mean square constructed from the quantity $\Sigma(\hat{y}-y)^2$ in the table equals 4.0399 with ten degrees of freedom. If the suggested straight line relationship between y and x is true, this mean square would also estimate the error variance σ^2. However, the ten degrees of freedom associated with the residual sum of squares can be broken into two components: the seven degrees of freedom associated with the error sum of squares and a remaining three degrees of freedom associated with the "Lack of Fit" sum of squares. At this point it is necessary to comment that the least squares procedure effectively "sees" only one value of the response at each setting of x, (although these individual values may be given different weights). Thus so far as fitting the model is concerned there are only five "observations" or degrees of freedom available to estimate coefficients in a mathematical model. The two statistics b_0 and b consume two of these five degrees of freedom. The remaining three degrees of freedom go to measure the variability of these "observations" about the fitted line. Of course, if the fitted model is a proper one, these three degrees of freedom will provide a measure of experimental error. However, if the proposed mathematical model inadequately explains the data, these degrees of freedom will provide a measure of experimental error, inflated by the failure of the model to fit the data.

The sum of squares associated with the three degrees of freedom for "Lack of Fit" are obtained by subtracting the error sum of squares from the residual sum of squares giving the "Lack of Fit" sum of squares in the Analysis of Variance table. Now, to repeat, if this lack of fit sum of squares is the result of experimental errors alone, then its mean square will be a valid estimate of σ^2. In the table this estimate of σ^2 equals 12.6997 with three degrees of freedom. The estimate of σ^2 from the repeated experiments equals 0.3286 with seven degrees of freedom. The F test shows these two estimates of variance to be significantly different. We therefore conclude that the proposed model inadequately describes the model.

Had the F test been non-significant we would have concluded that the fitted straight line was a reasonable approximation to the relationship governing the response, percent impurities, with the controlled variable, temperature. We would accept this conclusion because the model's failure to fit the data could be considered to be of the same order of magnitude as the experimental error. In the event of a non-significant lack of fit test it is important to note that the conclusion is *not* that the functional relationship between percent impurities and temperature is a straight line, but rather that the straight line is an adequate empirical representation of the response.

Fitting a Second Order Model

Since the example suggests that a straight line (a first order model) is an inadequate representation of the data, it is now proposed to fit a quadratic equation to the data, that is, fit the second order model

$$y = \beta_0 x_0 + \beta_1 x_1 + \beta_{11} x_1^2 + \varepsilon \qquad (14)$$

Some slight changes in subscript notation are to be noted. The controlled variable now appears as x_1 and its associated coefficient as β_1. The squared term, x_1^2, has for its coefficient β_{11}, the double 1 subscript indicating that it is a coefficient associated with a second order term. To estimate the three coefficients β_0, β_1 and β_{11} the data are arranged in the following fashion

Vector of Observations	*Matrix of Independent Variables*			*Doolittle Solution for Coefficients*			
y	x_0	x_1	x_1^2	b_0	b_1	b_{11}	
6.4	1	1	1	N	Σx_1	Σx_1^2	Σy
5.6	1	1	1		Σx_1^2	Σx_1^3	$\Sigma x_1 y$
6.0	1	1	1			Σx_1^4	$\Sigma x_1^2 y$
7.5	1	2	4				
6.5	1	2	4	12	36	136	124.0
8.3	1	3	9		136	576	452.0
7.7	1	3	9			2584	1920.0
11.7	1	4	16				
10.3	1	4	16	12	36	136	124.0
17.6	1	5	25	(3)	1	3	11.3333 10.3333
18.0	1	5	25				
18.4	1	5	25		28	168.0	80
				(2)		1	6.0 2.8571
							34.6667 34.6667
				(1)			1 1.0000

The mechanics of this Forward Doolittle parallel those for the first order model.[12,13,14] Solving equations (1), (2) and (3) for the coefficients in the fitted model we obtain:

$$(1)b_{11} = 1.000$$

$$(1)b_1 + (6.0)b_{11} = 2.8571;\ b_1 = -3.14$$

$$(1)b_0 + (3)b_1 + (11.3333)b_{11} = 10.3333;\ b_0 = 8.43$$

Thus the fitted equation is

$$\hat{y} = 8.43 - 3.14x_1 + 1.00x_1^2$$

The associated Analysis of Variance Table is

	ss	*df*	*ms*	
Crude Sum of Squares = Σy^2	1550.3000	12		
Due to b_0: (124) (10.333)	1281.3329	1		
$b_1 \mid b_0$: (80) (2.8571)	228.5680	1		
$b_{11} \mid b_1, b_0$: (34.6667) (1.0000)	34.6667	1		
Residual	5.7324	9		
Lack of Fit	3.4324	2	1.7162	$F_{2,7} = 5.22^*$
Experimental Error	2.3000	7	0.3286	

*Significant at the five percent level.

The sum of squares absorbed by each of the coefficients is, as before, calculated from the pairs of terms reading

down the right hand side of the Forward Doolittle Solution.

In deriving the sums of squares in the Analysis of Variance Table, the sequence of the terms added to the mathematical model is of great importance. The first estimate derived from observations is almost always their mean. The sum of squares absorbed by this statistic is called the "correction factor" and in a regression analysis is always the sum of squares attached to the estimate of the first coefficient in the model b_0. We note in passing that the coefficient b_0 does not necessarily equal the average response $\bar{y} = \frac{\Sigma y_i}{N}$ but rather depends in part on the nature of the model. The next step in complexity is the addition of a first order term associating y with x in the mathematical model. Thus the next sum of squares calculated is that associated with the first order coefficient b_1 given that b_0 has already been estimated. (Symbolically this is written as $b_1|b_0$; b_1 given b_0 has been estimated.) The sums of squares for b_0 and b_1 in this analysis of variance for a second order model will always equal those derived earlier when only a first order model was fitted. The next step in developing the model is the addition of the second order term. The sum of squares associated with the estimate b_{11} is now determined given that both b_0 and b_1 have already been estimated, that is $b_{11}|b_1, b_0$. We observe this additional sum of squares comes entirely from the lack of fit sum of squares in the Analysis of Variance Table for the first order model.

Once again we determine the adequacy of the fitted model by noting whether the variability about the fitted line, measured by the "lack of fit" mean square, is of the same order of magnitude as the experimental error mean square. The hypothesis that these two measures of variability are estimates of the same σ^2 is tested using the F statistic. In this example we note that even after fitting a second order model to the data a significant lack of fit continues to exist.

Alternative Models

Since a second order model is inadequate as judged by this statistical test, a third order model

$$y = \beta_0 x_0 + \beta_1 x_1 + \beta_{11} x_1^2 + \beta_{111} x_1^3 + \varepsilon \qquad (15)$$

could be fitted to the observations. It is of course clearly possible to continue to estimate the coefficients in a polynomial model of ever increasing order until an "adequate" fit, as measured by a non-significant F ratio for the lack of fit mean square, is obtained. However it is almost always wiser to think in terms of some other mathematical model rather than the simple polynomial expansion whenever a second order model proves inadequate. For example, for the above data, the model $\eta = \alpha e^{\beta x}$ might be tried. This model can be placed in linear form by taking the natural logarithms of both sides of the equation to give a new first order model

$$\ln y = \ln \alpha + \beta x$$

or simply

$$Y = \beta_0 + \beta x$$

where

$$Y = \ln y$$

$$\beta_0 = \ln \alpha$$

Orthogonal Polynomials

In fitting second or higher order models, considerable savings in numerical labor are obtained if the responses are recorded at equally spaced increments of the controlled variable. When this is done, the solution for the coefficients becomes quite rapid and, by slightly modifying the mathematical model (without however changing its order), the entire calculation procedure can be reduced to a minimum through the use of the Tables of the Orthogonal Polynomials. The use of these tables permits the rapid calculation of the sum of squares associated with each additional coefficient in the general k^{th} order model

$$y = \beta_0 + \beta_1 x_1 + \beta_{11} x_1^2 + \beta_{111} x_1^3 + \ldots + \beta_{11\cdots1} x_1^k + \varepsilon \qquad (16)$$

Tables of the Orthogonal Polynomials are given, with worked examples, in *"Statistical Tables for Biological Agricultural and Medical Research,"* Hafner, New York, edited by R. A. Fisher and F. Yates and again in the *"Biometrika Tables for Statisticians,"* Cambridge University Press (1954), edited by E. A. Pearson and H. O. Hartley. Many statistical texts include abridgements of these tables and include examples of applications. The text *"Statistical Theory in Research"* by R. L. Anderson and T. A. Bancroft, McGraw-Hill (1952) contains descriptions of both the Forward Doolittle Techniques and of the use of Orthogonal Polynomials.

If the response y is recorded at a haphazardly chosen array of settings of the independent variable x, the solution of the normal equations for the coefficients in the model can become quite burdensome. Thus the computational load is considerably reduced whenever the response can be recorded at equally spaced intervals of the controlled variables. This is certainly the simplest of experimental designs for fitting a response function. Of course a good experimental design will provide a measure of the possible lack of fit of the proposed model, and in addition supply a measure of experimental error that is independent of the model chosen. When there is only one controlled variable, all such experimental designs are called "One Dimensional". Quite obviously, once an experimental design has been set down, any number of different response variables can be measured at each setting of the controlled variable.

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BOOK REVIEWS

W. D. Baten, Editor

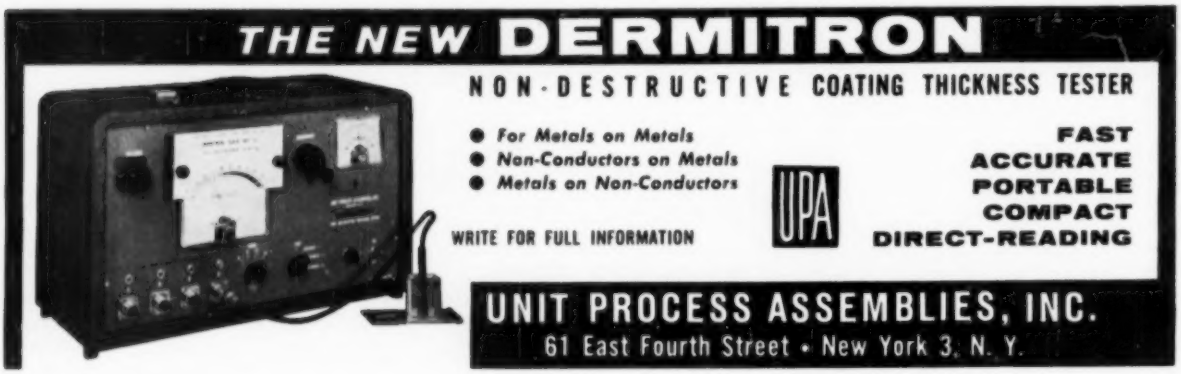
26 University Drive, East Lansing, Mich.

FUNDAMENTAL STATISTICS FOR BUSINESS AND ECONOMICS by John Neter and William Wasserman, Allyn and Bacon Inc. (Boston), copyright 1954, '56, 3rd Printing, 638 pages, price $6.95. Reviewed by Dr. Glenn L. Johnson, Michigan State University.

This book is a good text for its purpose which is to introduce students of business and economics to the field of statistics. It is good because it gives training in the handling and presentation of statistical data (Chapters I-VI) without failing to introduce probability and three of the important probability distributions—the normal, binomial, and poisson. It is also good because the important chapter on sampling is clear though elementary. The same is true of Chapters IX and X which distinguish between estimation and choices between hypotheses and do a nice job of explaining the difference. Quality control specialists will be pleased to know that the slant in the chapter on choices between hypotheses is toward business decisions and quality control; at times, they may regret that certain important concepts are referred to so incidentally and smoothly that the student may miss them while the statistician is unable to complain of their omission. Also, the omission of techniques applying sequential analysis to quality control will be regretted. The discussions of simple linear regression, index number construction, and time series analysis are clear.

Summing up—good coverage, well written with only incidental attention to certain very important fundamentals which we really do not expect students to master in their first course much as we would like them to do so.

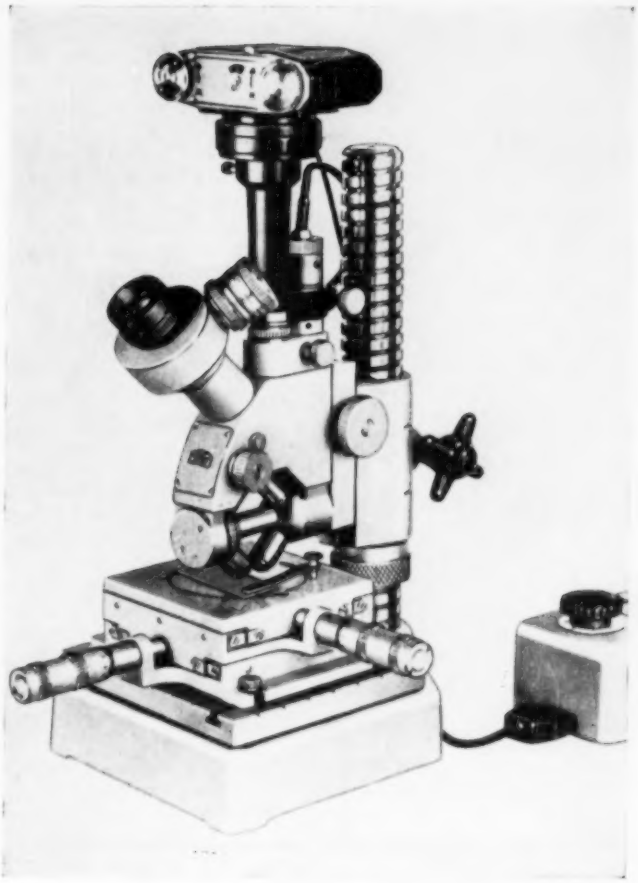
Now for some shortcomings—though the book is good for business administration students and economic students not headed for research, it is less adequate for the *scientific* student of economics. For such students, the handling of probability and probability distributions should be more detailed while the chapter on statistical decision making should focus more directly on the testing of hypotheses and cover sequential analysis. Applications of hypotheses testing in business decision making could well be concentrated in a section and related to game theoretic approaches to decision making. Moreover, as multiple regression analysis is an important tool for the economic scientist, the student should learn enough about it in an introductory course to read and understand research reports in which it is employed. Still further the index number problem of economics might very well be discussed in a statistics book for future economic scientists.



CARL ZEISS

WEST GERMANY

Light Section Microscope



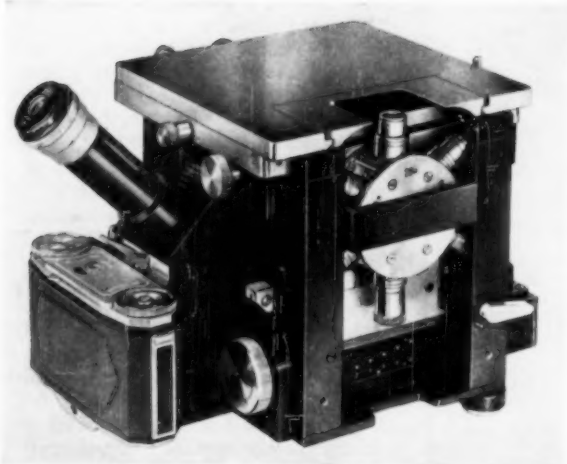
This microscope produces a profile of the surface being examined by the well known light-section method. Roughness depth, as well as the groove distances of machine-finished surfaces, can be measured. Internal surfaces can be examined by making *lacquer replicas.*

The newly developed revolving nose-piece for the objectives makes it possible to quickly change the magnification (height of profile) between 400x and 200x. At 400x, depths of roughness of 40 to 160 micro inches can be measured; at 200x, those of 120 to 4,000 micro inches.

Photographs for comparison and control purposes can be taken by mounting a 35mm miniature camera at top of the instrument.

In addition to the stage plate of the stand, a mechanical stage and center cradle (for turned parts) are available.

Interference Microscope



for measuring minute depths of roughness (80 to 1.2 micro inches)

This instrument, which has magnifications of 80x, 200x, and 480x, is designed especially for critical examination of super-finished surfaces, thickness of coatings, changes of surface structures due to wear, impact, stress, strain, corrosion, as well as for the studying of polished and etched metallurgical specimens.

It is equipped with built-in Thallium and white light illuminators.

A miniature camera, which is attached, provides photographs on 35mm film (1x1½").

Write for detailed literature on these instruments

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What's New?

ROY A. WYLIE, *Editor*
Ampex Corporation

P-12-1—Greater control of a combination of textile inspection equipment is offered in the new Lindly Multicontrol Model 602. The new unit can be used with various modular plug-in amplifiers to control two Automatic Yarn Inspectors, End Break Detectors, or Thread and Line Inspectors, or a combination of any two of these devices. Additional amplifiers provide control for a Spun Yarn Inspector or Slave-Master Yarn Inspector operation. The Multicontrol is used in conjunction with these electronic and photo-electric devices to count defects in these operations, and can be set to automatically stop production machines when a non-permissible defect is registered, thus improving yarn quality appreciably. Broad band amplifiers in the new plug-in units, available in single or dual amplifier modules, permit detection of defects of almost any configuration. The plug-in feature permits quick replacement and minimum machine downtime. A visible fail-safe device is incorporated in the Model 602 to indicate failure or reduced sensitivity of the phototube, or the burnout of the lamp. This eliminates the possibility that yarn will pass uninspected due to these causes. New circuitry increases the life of the phototube many times, while the RF powered lamp, with feedback control, offers exceptional sensitivity and stability. Costly false stops due to power fluctuations are eliminated.

★ ★ ★

P-12-2—"Diatest" High-Precision small bore gages now cover a range of diameters of 0.057 in. to 1.130 in. Previously, three sets, E-1, E-2, E-3 were available for gaging sizes and discrepancies in bores of 0.057 in. to 0.828 in. Now added to the line is set #E-4 which covers diameters ranging from 0.820 in. to 1.130 in. Diatest bore gages are accurate to within 0.00008 in., and all sets overlap in size to assure complete range. All parts are obtainable separately. Included in the Diatest line are the following accessories:

Right Angle Attachment—permits gaging without removing workpiece from under bore spindle.

Extension Rods—may be used to length of 30 in., without loss of accuracy.

Depth Adjusters—used in conjunction with extension rods to permit readings to any defined depth.

★ ★ ★

P-12-3—Military approved for field use, the Dit-Mco Universal Automatic Electric Circuit Analyzer has been assigned the number, AN/USM-88. The Analyzer will accurately and automatically test every type of complex, multiple, interconnected circuitry for shorts, continuity and insulation flaws, and also will functionally test relays, solenoids, actuators and other resistive devices. This is done at the rate of approximately 10 circuits per second. An electronic "Go" and "No-Go" method of detection is employed to guard against borderline defects which pass undetected in functional type tests. Defects are located and identified instantly by means of a visable matrix type reference chart. Indicating type fuses have been placed on the front panel and the Analyzer is shockproof, completely waterproof, and portable. It was designed to meet the requirements of MIL-T-945A. Circuit testing capacity is 144 circuits.

★ ★ ★

P-12-4—The Go-Devil Monitor, dial indicator checker and self mastering comparator, is a low cost instrument that can check to an accuracy of better than 0.000025 in., without the use of setting masters or gage blocks. As a dial indicator checker the Monitor may be used to check more than 300 different models of indicators at a rate of one indicator in two minutes. Indicators with ranges up to 1 in., and graduations of 0.001 in., 0.0005 in., 0.00025 in., 0.0001 in., and 0.00005 in., are easily handled. When the Monitor is used as a small parts comparator, set-up takes less than one minute, and no masters or gage blocks are needed. Large setting graduations permit reading to 0.000025 in., and the use of any dial indicator. The Monitor is completely portable, needing no

Send for Information

Additional information regarding new products or new literature items appearing in the What's New? department can be obtained by writing in the key number of the item in the Product Education Service coupon which appears on page 38.

13th Midwest Quality Control Conference Transactions

The transactions of the Nov. 6-7, 1958 13th Midwest Quality Control Conference are now available from the National Office in a bound volume.

Over one hundred pages of valuable technical knowledge and practical applications of quality control are ready to become part of your complete SQC library, NOW!

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air or electricity. A ¼ In., diameter anvil is standard. Price of the Monitor is $175.00, less indicator, but with an attractive wooden case.

★ ★ ★

P-12-5—A new microwave spectrum analyzer has been added to the Panoramic line of instruments for measurement and analysis of various spectra. The new SPA-4 covers frequencies from 10 mc to 44,000 mc with one tuning head. Compact and low in cost, it is an excellent general purpose instrument and ideal for applications requiring exceptionally high sensitivity. Resolution is continuously variable from 1 kc to 80 kc for analysis of wide and narrow pulsed RF signals. A sweep width of 70 mc, which is continuously adjustable down to 0 mc, makes possible wideband observation of the overall frequency range of interest or high resolution analysis of small segments. Careful shielding avoids interference. Amplitude scales are calibrated for both voltage (linear) and power (square) as well as log. An accurate direct reading linear slide rule dial lights up band in use. The SPA-4 is simple to operate and may be used for the analysis of FM, AM and pulsed systems, instabilities of oscillators, noise spectra, detection of parasities, studies of harmonic outputs, radar systems and other signal sources. Constructed to Mil specifications, the SPA-4, like other Panoramic instruments, is designed to meet performance requirements over long periods of hard usage.

★ ★ ★

P-12-6—A new instrument to enable producers and buyers of filter papers and similar porous materials to quickly and conveniently measure porosity without sample preparation has been announced. Known as the constant-flow Porosimeter instrument, it indicates the degree of porosity by measuring the resistance the material has to the passage of air. The more porous the material the less the resistance to the flow of air through the sample and vice versa. Porosity or permeability is instantly indicated on a calibrated dial at the front of the tester. The instrument is about the size of a typewriter, sits on a bench or table, or can be placed on a cart and rolled about the plant. It connects to the regular factory air line. Uses for the new instrument include inspection of incoming raw stock before conversion, production inspection during processing in both laboratory and mill, and in final inspection. To

Multi-exposure shot showing "PERMANENT" mounted prism being crashed into a piece of wood. Bond was not affected in any way. Your AO Sales Representative will perform this demonstration right before your eyes.

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set up and use, the operator places the material on the test station and clamps it firmly in place between two rubber seals with a pneumatic foot valve. Air flow is through an orifice in the center of the seal. Hands are left free for handling samples and recording results. The instrument can be used to check a wide range of porosities. The standard model is supplied with four different size orifice seals, making it possible to test small areas on highly porous materials and large areas on denser materials.

★ ★ ★

The Japanese Standards Association has available for distribution a set of 20-face dice which can be used for generating random numbers. Each die is a regular icosahedron and has numbers from 0 to 9 engraved twice each on its faces. By throwing this die, numbers from 0 to 9 will appear with equal probability, so that sequences of random numbers are easily obtained. The dice come in a set of three colors: red, yellow and blue. It is possible to obtain random numbers with three digits in one throw by letting, for instance, blue stand for the first digit, red for the second and yellow for the third. Random numbers of six digits can be generated by rolling the dice, twice, etc. The price for the set of dice is $2.50 plus $.70 postage. Up to nine sets will go at the same postage rates. The dice are packaged in a handy plastic box. *Orders, with remittance, should be sent to: Japanese Standards Association, Kobikikan-Bekkan Bldg., Ginza-Higashi 6-1, Chuo-Ku, Tokyo, Japan.*

★ ★ ★

Si Collier Named Chairman of ASTM Committee E-11

Si Collier, director of quality control of the Johns Manville Corp., past president of ASQC, and presently a member of the Society's Financial Advisory Committee, was named Chairman of the ASTM Committee E-11 on Quality Control of Materials. Mr. Collier succeeds Harold F. Dodge, Bell Telephone Laboratories (retired) and presently with Rutgers University, who served as chairman from 1946-58.

The new vice-chairman of the Committee is Charles A. Bicking, Carborundum Co., and the new Secretary is James H. Davidson, General Electric Co. The retiring-secretary is Oliver P. Beckwith, William Carter Co., who served concurrently with Mr. Dodge from 1946-58. Both Messrs. Dodge and Beckwith will remain active on the committee.

The total members of Committee E-11 are: R. C. Adams, O. P. Beckwith, C. A. Bicking, R. A. Bradley, S. Collier, J. H. Davidson, W. Edwards Deming, H. F. Dodge, R. H. Ede, W. P. Goepfert, F. E. Grubbs, R. J. Hader, Gerald Lieberman, B. H. Lloyd, John Mandel, C. L. Matz, E. G. Olds, W. R. Pabst, Jr., L. E. Simon, Louis Tanner, Grant Wernimont, and W. J. Youden.

New Literature Available

L-12-1—A new 24-page catalog of Pye Scientific Instruments completely describes products such as Pye amplifiers and voltmeters; fluxmeters; galvanometers; Kelvin and other type bridges.

♦ ♦ ♦

L-12-2—Publication of a scientific brochure on the subject of Glennite instruments and instrumentation systems, has been announced by Gulton Industries, Inc. Entitled, "Measurements and Controls", the four-page, two-color, illustrated brochure highlights Glennite instruments for shock, vibration, pressure, inertial control, temperature and other devices for use as single components or in complete systems. Included in the description are such instruments as transducers, amplifiers, cables and connectors, vibrators, interferometers, strain gages, accelerometers, temperature probes and miniature airborne recorders.

♦ ♦ ♦

L-12-3—Non-Linear Systems, Inc., announces the availability of a new Short Form Catalog that describes and provides specifications on the company's exclusive line of "Oil Bath Stepping Switch" type Digital Voltmeters, Ohmmeters, Ratiometers and associated accessory equipment. This condensed catalog also offers a speedy reference on digital voltmeter characteristics and provides an instrument selection chart and ordering information.

♦ ♦ ♦

L-12-4—A revision of American Standard B5.30—Knurling—has been approved by the American Standards Association and published by the American Society of Mechanical Engineers. Tooth depths for diagonal knurls have been added to the standard, and various editorial changes have been made in the revision for the sake of greater clarity.

♦ ♦ ♦

L-11-1—An illustrated catalog, listing the various models of the National Fontar Borescope has been published. The Borescope is an instrument that, in effect, takes the eye close up to an otherwise inaccessible internal inspection area, so that it may be seen with clear, bright, accurate definition.

♦ ♦ ♦

L-11-2—A combination catalog and informative handbook has just been printed and is available. General Catalog #10 consists of 144 pages, 8½ × 11 size, with high gloss, stain resistant covers, and plastic binding. Over half its content is well organized information on the highly technical subject of optical gaging, chart-gages and fixturing. The book is indexed with die-cut tabs covering sections devoted to Chart Layout Methods, Standard Chart-Gages, Micro-Gage Chart-Gages, Standard Accessories, Projector Tracers, Custom Chart-Gages and Fixtures, and Contour Transcribers. It is illustrated with large clear pictures and many of the pages are printed with a second color to aid illustrative effect.

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The Quincunx is a must for presentation of basic quality control principles. Demonstrates visually to your audience how a Normal Distribution pattern is formed. Also demonstrates how various Non-Normal distributions are formed.

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section briefs

ALLENTOWN-BETHLEHEM . . . The October meeting was very enjoyable due largely to the excellent talk by Frank Caplan, Jr. of Westinghouse Electric Corp. He briefly discussed problems encountered in aluminizing television picture tubes and the statistical techniques used in solving the problems.

The first committee meeting for the Joint 5th District Industrial QC Conference, to be held Mar. 21 at the Hotel Traylor, resulted in the general consensus that plans are progressing very well.

The executive committee held its regular meeting on Oct. 22. Membership renewals were reported to be progressing satisfactorily; the educational program has reached the halfway mark and results are very encouraging; the Saddoris Award position was disclosed; and local participation speakers were discussed. At the end of the meeting, a professionalism questionnaire was distributed to representatives of the various industries.

BALTIMORE . . . At the October meeting, Willard Allphin of Sylvania Electric Products, Inc. presented an interesting discussion on the subject of "Lighting for inspection." Mr. Allphin described several principles involved in lighting inspection tasks and gave several practical demonstrations on the effect of lighting in increasing ability to see small details. He emphasized the importance of the inspection task being the criteria for the type of lighting desired.

Prior to this meeting, the second of seven basic QC training sessions was presented by Frank Gryna, senior quality assurance engineer of The Martin Co.

BATTLE CREEK-KALAMAZOO . . . The Nov. 17 meeting was a joint meeting with the local ASTE group. Harmon Bayer, quality control consultant, gave a very interesting and illustrated talk on machine capability studies. Mr. Bayer's talk was entitled "Quality capability analysis of tools and equipment."

Frederick McIntyne, Office Civil Defense Mobilization, is in the process of organizing an administrative applications group within the section.

Phillip Harris, section membership chairman, has announced that an active membership campaign will be in progress through February.

BINGHAMTON . . . The November dinner meeting was held at St. John's Ukranian Social Club in Johnson City. Guest speaker for the evening was Paul M. Miller, Middletown Air Materiel Area, Olmstead AFB, Pa. His topic was "Air Force procurement QC—procedures for electronic equipment," which proved to be an interesting lecture for all members and guests (especially those employed on military contracts).

The Jan. 20 meeting to be held at the Elks Lodge at 7 pm will feature a DoALL Company lecture entitled "The story of the cutting edge." The lecture will depict the importance of cutting tools as a basic QC consideration.

BIRMINGHAM . . . The 5th annual QC conference was held Oct. 23-24 at the University of Alabama. This year's program was again divided into two sections—the basic section for those persons just beginning their work in QC and the advanced section for managerial and supervisory personnel. Speakers and discussion leaders included: Richard S. Bingham, A. C. Rosander, Axel Sternlof, Larry Jones, David M. Chambers, Hunter H. Roberts, and Verne Reckmeyer. The section would like to thank the University of Alabama for the excellent program.

Prof. Wyllys G. Stanton will discuss "Reliability problems in QC" at the Jan. 16 meeting to be held in Tuscaloosa at the Hotel Stafford.

BOSTON . . . A joint meeting with the Merrimac subsection was held Oct. 9. The Western Electric Co., North Andover, acted as host for the group. Henry M. Wolfson, superintendent of inspection, arranged a very interesting tour. The group was able to see SQC applied to a "non-homogeneous universe."

BUFFALO . . . The section was host to the 2nd annual conference of the Chemical Division which was held Oct. 2-3 at the Hotel Statler-Hilton. A total of 275 registrations were received thus making the conference a complete financial success.

BUZZARDS BAY . . . A panel discussion highlighted the October meeting. The subject was "How QC operates in my company" and was presented by a panel composed of: Kenneth Bennett of Revere Copper and Brass Co., Walter Nichols of Aerovox Corp., and Kenneth Chace of Berkshire-Hathaway, Inc. Section chairman Hans Picard served as moderator. A lively question period concluded the informative program.

CHATTANOOGA . . . The section met Oct. 22 to hear a timely address by Richard S. Bingham, Jr. of the Carborundum Co. Mr. Bingham presented "Sharpen engineering judgment with statistical methods."

CHICAGO . . . The general meeting of Jan. 14 to be held at the Furniture Mart (666 N. Lake Shore Dr.) features Henry J. Jacobson of Sutherland-Jacobson & Associates as the evening's speaker. Mr. Jacobson will talk on "The administration of an inspection program." In the past and up to the time of his move to Cincinnati, Henry was one of the most active officers of the section. Prior to Henry's talk, Peter Kuffner of the local air procurement district will discuss government acceptance sampling tables in his afternoon talk which will be followed by dinner and a social hour. Dinner reservations are $3.75.

A 16 week program on principles and procedures in precision measurement will start at 7 pm on Jan. 20 at the University of Illinois, Room 218, Navy Pier. The course will cover the use and handling of precision measuring instruments in the metal working industry. The cost per student will be about $65 which covers the 16 meetings and includes the text.

CINCINNATI . . . At the October meeting, Norman E. Girardot of Pabst Brewing Co. gave a talk on "Recent developments in the measurement and control of flavor." This important evaluation for any food or beverage has been formalized in recent years. Methods and examples on the criteria of sensitivity, reliability, and validity were thoroughly covered. The coffee talk speaker was Paul Miller, program director of Cincinnati's WCKY, who spoke on "The history of radio." His talk was both entertaining and educational.

The theme of the 8th annual all-day conference to be held Jan. 31 will be "E. A. S. E. of QC." Prominent speakers will present: **Education** for the job; **Assets** in planning the job; **Selecting** the best methods for the job; and **Experience** in practical problems on the job.

CLEVELAND . . . Many of the members were fortunate to sit in on an informal discussion with Dr. Milton Terry prior to dinner at the October meeting at which Dr. Terry talked on "Analysis of planned experiments." All of those who heard Dr. Terry were impressed with his knowledge and enthusiasm for the right way of doing an experiment.

The executive committee met on Nov. 28 to discuss and make final plans for the educational committee's fall course. It was agreed to hold a course at the Hotel Carter for six weeks on the subject of "A simplified presentation of analysis of variance and experimental design." The course will be taught by Dr. J. N. Berrettoni and H. M. Wadsworth of Western Reserve University and Dr. F. C. Leone of the Case Institute of Technology. As the course is open to the public, a full registration is expected.

A group of approximately 50 Akron-Canton area members asked the section for permission to form a new section. The letter of request shows considerable interest among a large number of individuals and most of the leading Akron-Canton firms were represented. The executive committee gave 100 percent approval to the request.

COLUMBUS . . . On Oct. 15, the section held a plant tour of the bearing factory and shipping center of the Timken Roller Bearing Co., Bucyrus. There were 119 members and guests who viewed the automated machinery and modern material handling equipment.

The death of chairman Albert E. Haigh and the transfer of our treasurer has resulted in the following officer changes: chairman—W. Ray Miller, Jeffrey Mfg. Co.; secretary—Donald E. Seelbach, Denison Engineering; treasurer—Emery Gill, Jr., Kimble Glass Co.

At the Jan. 21 meeting, John W. Gower will present a talk on "The evolution of the legal aspect of quality." In his

ALBERT E. HAIGH

The Columbus section regrets to announce the death of their chairman, Albert E. Haigh, at the age of 53 who died following a brief illness in St. Anthony's Hospital on Oct. 31. Mr. Haigh was born in Barrow-In-Furness, England and received his education in that country. Ed served Timken Roller Bearing Company for twenty-four years and at the time of his death was general foreman of finished assembly and final inspection. In addition to being very active in the section and serving in many capacities, Mr. Haigh was very active in the Masonic Order and the Columbus Power Squadron. The section will greatly miss the genial warmth, untiring efforts, and unceasing leadership displayed by Mr. Haigh.

talk, Mr. Gower will develop the background of a company's responsibility for the quality of its products.

The section is conducting a basic SQC training course. The instructors are: Roy Cowin, quality manager of Kimble Glass Co.; and Kenny Brooks, quality engineer of General Motors Ternstedt Div. Both instructors are experienced in teaching QC subjects and have wide experience in in applying statistical analysis methods to practical problems.

CORNING-ELMIRA . . . Approximately 50 members and guests attended the Oct. 14 meeting at Cornell University to hear the interesting talk "Design of experiments" by E. C. Harrington of the Monsanto Chemical Co. Mr. Harrington developed the concept of response surface equations, showing some examples of problems that would have yielded no solutions a few years ago lacking this concept.

DALLAS-FORT WORTH . . . In a short business session during the regular October meeting, a proposal authorizing the executive committee to establish a section scholarship loan fund was unanimously adopted. The executive committee will obtain necessary approval from the National Scholarship Award Committee. After the business phase, J. Y. McClure gave an inspiring talk on "Management's responsibility to QC." As the title indicates, many thought-provoking ideas and concepts, new to the majority of the 83 members and guests present, were presented.

The basic SQC course which was started in October is being enthusiastically received by management of local industry. More than 50 QC people have enrolled. Many of them are joining the Society for the first time.

At the Jan. 15 meeting, Dr. E. F. Moore, Astrodyne, Inc. of McGregor, will speak on "The design of experiments."

DANVILLE-SUNBURY . . . Dr. Ellis Ott spoke at the Oct. 21 steak dinner meeting at the Hotel Berwick. His subject, "Trouble shooting with attributes," was of interest to all. He also introduced a challenging topic with his presentation of an "Evaluation of your company's QC program" which he has tried with some of his former pupils.

The Sept. 16 plant tour of ACF Industries at Milton was shortened and supplemented by a grand tour of the plant of American Home Foods, Inc., home of Chef Boy ARDEE products and the pride of section chairman Jay Wagner.

DAYTON . . . On Oct. 2 section members and guests were participants of a tour of the Monsanto Chemical Laboratory. This was the first plant tour of the year and those who were present were shown the various testing equipment used by the research and engineering lab.

The introductory SQC course is nearing completion and the education committee is working with the Dayton Board of Education to have this course added to the adult education program.

The Jan. 8 meeting will dispense with the usual technical meeting and instead the members will gather together and enjoy the annual social meeting, complete with refreshments, movies, and games.

The section has cancelled the annual all-day conference in favor of the Aircraft and Missile Division Conference of which the section is host.

DELAWARE . . . The first meeting was a ladies' night program which proved to be most successful. Dr. and Mrs. Ellis R. Ott talked and presented slides on their trip to India. Dr. Ott is chairman of applied and mathematical statistics at Rutgers University.

The Jan. 8 dinner meeting will be highlighted by the presence of Andy Rodger, manager-production control of International Latex Corp., who will speak on "The sales forecast—past, present, and future." Mr. Rodger is chairman of the production control committee of the Society's Administrative Applications Division. Prior to dinner, a clinic session will be held. R. W. Kennard of the Dupont Co. will discuss "Regression analysis—design of and case study." A good turnout is expected for both the clinic and after dinner meeting. The subjects to be covered should prove educational as well as entertaining for those attending.

DENVER . . . On Oct. 9, a social hour, compliments of the Sundstrand Turbo Co., was held at the Boulder Country Club. After a delectable dinner, Jerry Posakony of Automation Instruments, Inc. gave a very interesting talk on "Ultrasonics' place in today's QC."

Abram Raick presented "The progress of SQC in India" at the Nov. 13 meeting which was held at the plantation in Littleton. Mr. Raick, Colorado Fuel & Iron of Pueblo, recently spent some time making a study of this subject in India.

EVANSVILLE-OWENSBORO . . . A joint meeting with the Evansville chapter of ASTE was held on Oct. 13. C. G. Schelly, director of educational research for the DoALL Co., presented an illustrated lecture on "The story of the cutting edge."

Robert H. Mayes, QC manager for Shenley Industries of Louisville, will be the speaker at the Jan. 20 meeting to be held in Owensboro. Mr. Mayes' subject will be "QC applications in the distilling industry."

GREATER MUSKEGON . . . The section had the pleasure of having Society President C. E. Fisher as guest speaker at the October meeting. Mr. Fisher expounded on the

ELECTRONICS DIVISION NEWS

5th National Symposium, RQC

Plans for the Symposium, to be held at the Bellevue-Stratford Hotel in Philadelphia on Jan. 12-14, have been finalized. (See special announcement elsewhere in this issue.) Many members of the Division have been active in arranging this event. Our own past chairman, Irv Schoeninger, is this year's General Chairman. The program will include papers and panels on a great variety of subjects, including Cost of Reliability, Training and Education, Mathematical Theory, Field Reliability and Maintainability, Reliability Tests and Measurement, Management of Quality-Reliability programs, and others. Hank Schumer, Division Chairman, will present the first annual Electronics Division Award at the Symposium. Bob Fitzgibbons is chairman of the Awards Committee.

Reliability Assurance Training Conference

Your Education Committee, under the chairmanship of Frank Gryna, has been busy with plans for a reliability training conference. The Division is co-sponsoring this course with the IRE Professional Group on Reliability and Quality Control. The present schedule calls for a ten-day course on Oct. 19-31, 1959 to be given in the Baltimore area. If successful the course will be repeated in other areas as demand indicates. This first course will endeavor to cover the entire field of reliability philosophy, measurement, and control. It will be a survey type course intended to provide orientation and perspective. The General Chairman of the training conference is Cliff Ryerson.

Technical Publications Committee

This committee, under the chairmanship of Dick Myers, has completed the draft of a *Production and Field Reliability Handbook*. This manual will be, for the most part, a collection of papers, articles, and procedures previously published. They will be collected and edited under the above central theme. It is planned that the handbook will be available by early Spring, 1959.

Councillor Activity

The Philadelphia section, with cooperation from representatives several of the divisions, put on a unique program in October. During the first part of the program, Warren Purcell discussed the provocative question, "Who Controls Quality and How?" Then the meeting broke up into professional interest groups. Members of the Electronics Division participated in a stimulating discussion led by Bill Rombach on a comparison of Army, Air Force, and Navy quality assurance specifications.

The Philadelphia section and the District Councillors are to be commended for this fine program and the increased service to members of the Society which it has afforded. Here is a good model for councillors of other districts to follow!

present and future objectives of ASQC and its program to date. The meeting was held at the Spring Lake Country Club.

The January meeting will be a plant visitation of the Norge Div., Borg-Warner Corp., manufacturers of electric stoves, refrigerators, washers, and dryers. The plant tour will be preceded by a dinner at Bill Stern's Steak House. Past attendance at plant visitations has always indicated high interest appeal.

HAMILTON . . . Some 35 members and guests were in attendance on Oct. 16 to hear Dorian Shainin deliver his talk on "A managerial perspective of inspection, QC, and statistical engineering." Mr. Shainin's explanation of "avoidable costs" and his approach to the reduction of these costs was expertly outlined and enthusiastically received by the group.

A basic SQC course is being conducted at the John F. Ross Vocational School in Guelph in cooperation with the section. Some 20 registrations have been made in this course.

HAMILTON-MIDDLETOWN . . . The October meeting was held at Champion Paper & Fiber Co. The speaker for this meeting was A. W. Young, Johns Manville. Mr. Young presented the QC picture as practiced at the Richmond, Ind. plant of Johns Manville. Excellent films on QC and asbestos were shown.

The Jan. 14 dinner meeting will be held at the Anthony Wayne Hotel. The speaker for the evening will be Charles Bicking, manager of QC, The Carborundum Co. Mr. Bicking's topic will be "Experimental design in research and QC."

. . . Harrisburg—Martin H. Wohlbruck, formerly of Schick, Inc., transferred to the Allentown-Bethlehem section and Thomas E. Diviney, formerly of Sylvania Electronic Products, Inc., transferred to the Boston Section.

HARRISBURG . . . Dr. J. Fred Verigan spoke at the Dec. 3 meeting at Hostetter's, Mt. Joy. Mr. Verigan is QC manager at Crown Cork & Seal Co., Baltimore. His subject was "Selling plant personnel on QC." This is a major problem faced by most QC people. Mr. Verigan has had wide experience which fitted him to present this subject in an interesting as well as informative way.

Dr. Allen Crawford, Esso Research & Engineering Co., will be guest speaker at the Jan. 7 meeting. His subject will be "The design and analysis of industrial experiments." Mr. Crawford will discuss the ways and means of setting up experiments or tests to give us data which will tell the best way to control faulty processes or to improve processes for which specifications are tighter than the process capabilities.

HARTFORD . . . A "problem workshop" was conducted Oct. 7 at the plant of Heublein, Inc. The session was opened with a tour of the bottling lines and rectifying facilities followed by a discussion period covering problems related to rapid and accurate fill height determinations. The panel, headed by Sid Clark, concurred with Dorian Shainin's suggestion that attempts to determine net contents by weight should be abandoned and that a refined volumetric procedure be followed. The use of a "Run-reset" card to govern filling machines adjustments was recommended.

The first monthly meeting of the season was held at Club Alden on Oct. 21. Eugene Grumman, chief engineer of Bullard Machine Co., spoke on "Machine capability." Problems encountered in, and benefits derived from machine capability studies inaugurated at Bullard Co. several years ago were discussed. Included was the psychological approach followed in setting up "do-it-yourself" inspection and gauging procedures. At the conclusion of his speech, Mr. Grumman presented Mr. Thomson of the Mark Twain Memorial with an original complete set of plans for Mr. Clement's house built in Reading, Pa. about 1907.

HUNTSVILLE . . . The section teamed up with the Birmingham section and the University of Alabama in sponsoring the 4th annual QC conference which was held at the University of Alabama on Oct. 23-24. A most interesting and informative program was presented.

INDIANAPOLIS . . . On Oct. 14 Rodger Heimlich conducted a discussion period which gave all present much food for thought. Rocco L. Fiaschetti, Ansco Film, gave a very interesting talk on basic QC. The meeting was well attended.

Quality Control day in Indianapolis—The Mayor of Indianapolis has proclaimed Jan. 20 as QC day. The section will have a booth at the 13th Midwest QC Conference in order to pass out information on the 14th conference which is to be held at French Lick, Ind. in 1959.

It appears the section has achieved a method to promote good fellowship and a time to discuss current problems in the "koffee-klutch" which is held in the cafeteria at the end of each meeting.

The local committee for professional development has completed an analysis of the section survey in time to distribute source material to members for participation in the coming panel-forum on "Quality control as a profession." According to the survey, one out of two central Indiana industries do not have a QC engineer and one out of four do not mention QC in job descriptions.

Two evening courses in QC are again being offered at Arsenal Tech High School. The subject of the beginner's course is "Fundamental concepts of variation" and the advanced course deals with "Acceptance sampling." The later course should be preceded by the beginner's course.

KANKAKEE-JOLIET . . . Dr. Carl Larson of General Tire and Rubber Co. spoke on "Quality control philosophy: government-industry" at the Oct. 6th meeting. He indicated that quality responsibility lies with the contractor. A good discussion followed his stimulating talk.

LEXINGTON . . . On Sept. 11, 1957, several executives representing various industries in and around Lexington, contacted the local Chamber of Commerce regarding the formation of an ASQC section.

Hogan Trammel, assistant secretary of the Chamber of Commerce, and his associates started immediate action by contacting W. E. Barker, Cincinnati section chairman. A meeting was planned and conducted which was co-sponsored by the Cincinnati and Hamilton-Middletown sections. The meeting was held Oct. 8 and in attendance were: Louis Fitzgerald (who presided), Gordon Thompson, Dr. Harry Smith, William Barker, John H. Kloecker, Jim Maloney, J. S. Gantt, Dave Birch, Don Brandt, General Ackley, and Larry Girton.

A second meeting was held on Jan. 16, 1958. At this meeting, a "pro tem" nominating committee and officers were elected to begin the function of the group as a subsection of the Cincinnati section.

On Feb. 13, an organization meeting was held. The nominating committee made recommendations and the following officers were elected: chairman—D. G. Dunn, IBM Corp.; vice chairman—L. E. Girton, Proctor and Gamble; secretary—Don Freeman, Lexington Signal Depot; and treasurer—W. S. Winfrey, Berea Rubber Co. The constitution was read and adopted.

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By the first of March, an adequate number of membership applications were obtained thus making it possible to apply for section status. On Mar. 20, the section charter was presented to chairman Dunn by Society President Leon Bass.

In a short 5 months from the first organization meeting, the Lexington group was officially recognized as a section—a notable achievement.

LOS ANGELES . . . The Nov. 12 meeting was summarily honored in that it was turned into a joint meeting with the Institute of Environmental Engineers. Allen J. Silver of Radioplane Div., Northrup Aircraft, Inc. was the added speaker. Mr. Silver and Mr. Boswell discussed the many phases of "outgoing QC."

LOUISVILLE . . . The Oct. 13 meeting was held at Bellarmine College. There was a social period from 6:30-7:00 after which a delightful meal was enjoyed by 34 members and their guests. The president, Mr. Lipps, called the business meeting to order promptly at 8:15. Patrick Dellerio presented an informative program education capsule on the use of "Rank correlation." The program for the evening was a panel discussion on "QC at the crossroads." Oscar Biship was moderator with Ned Miles as co-moderator. The panel consisted of Miss Fay Smith, Al Green, Ray Donnally, and M. J. Oates. After the moderator gave an introduction to the subject, each panelist related some past experiences and the applied solutions to these periods of crisis. The unified theme of the answers to the several questions asked of the panel was the development of an efficient future of our individual QC system systems by our alertness today.

MEMPHIS . . . H. M. Truax, manager of QC for Atlas Powder Co., was the guest speaker at the October meeting. His subject was "Probability applications to control charts and statistical tests" which gave the members many new ideas.

METROPOLITAN . . . The section presented another provocative program at the Oct. 2 meeting. The program was moderated by D. W. Thomas of Western Electric Co. who introduced the speaker, D. G. Meckley, III, director of engineering of the Tappan Stove Co. Mr. Meckley spoke on "The inspection function" and threw a searching sympathetic light on the subject. He covered the field and spotlighted some common incompatible answers among such subjects as inspector selection, pay, training, responsibility, standards (and variations therefrom), diplomacy, and more. A pre-meeting clinic was conducted by C. J. Keyser of the technical staff of Bell Telephone Labs.

On Jan. 15 at 6:30 pm the annual dinner meeting will be held at the Hotel Shelburne in New York. The meeting will be addressed by Society President C. E. Fisher on the subject "ASQC—its objectives and its program." Simon Collier will then take up 'People—as it pertains to QC."

The annual one-day Stevens chemical conference will be held at the Stevens Institute of Technology on Jan. 24.

MID-HUDSON . . . William J. Masser, General Electric Co., spoke at the Oct. 7 dinner meeting. He explained the duties of a quality program with special emphasis on controls, incoming material, and special processes. His talk was thoroughly enjoyed by the 44 members present.

The guest speaker for the Jan. 6 meeting will be Dorian Shainin whose topic is "How Management uses QC to reduce operating costs."

MILWAUKEE . . . Forty people attended the October dinner meeting and heard an interesting talk by Irv Schoeninger of Globe Union, Centralab Div. Irv, who is well known nationally and is an ASQC Fellow, talked on "Using SQC in manufacturing and engineering." Prior to the dinner meeting, 27 persons attended dual training sessions on "Introductory probability" and "Regression analysis."

The January meeting will feature Bill Golomski, junior past section chairman and director of operations research for Oscar Mayer & Co., speaking on, what else, "Operations research."

Larry Linson, Bucyrus Erie Co., has assumed chairmanship of the section's 6th industrial clinic for QC.

MONTREAL . . . The 2nd annual all-day forum was held on Oct. 25. Forum speakers were: W. A. MacCrehan, Frank Gryna, Dr. R. B. Murphy, W. R. Purcell, C. A. Baumann, L. J. Lacey, R. G. Belcher, and Allin Deacon. A basic SQC training course was presented by M. J. O'Callaghan and W. Pukalo. Dr. A. V. Feigenbaum spoke at the luncheon. Many thanks go to the fine committee for this successful forum. The committee consisted of: E. C. Beckett, Miss F. G. Walters, C. I. Taylor, F. Clow, J. B. Pringle, R. Lessard, J. St. Pierre, A. F. Schmidt, D. M. Park, R. Couch, Z. Miller, and G. Williams.

On Oct. 29, R. M. Jacobs of RCA Missile and Radar Dept. addressed a joint meeting of the section and the Canadian Aeronautical Institute.

R. Cardno of Canadian General Electric will be guest speaker at the first meeting in 1959 to be held on Jan. 14.

Kingston-Brockville Subsection . . . The second fall meeting was held Oct. 8 at Automatic Electric (Canada) Ltd. Garnet Eller, manager of QC, explained how the sound application of statistics has enabled the company to maintain continued production of a variety of automatic telephone equipment used in modern automatic exchanges. During a tour of the plant, the members were able to see just how this company has used SQC to become one of the world's leading manufacturers of automatic electrical control and communication equipment and systems.

The "Statistical methods in industry" course in industrial experimentation being presented at Queen's University has an enrollment of 58. The course is co-sponsored by the subsection.

MUNCIE . . . Members and guests were treated to an interesting evening when a tour of the RCA Marion plant was conducted on Oct. 16. An excellent dinner was followed by an excellent chance to walk it off. Guides were plentiful and exceptionally well informed. All of those present agreed it was one of the best conducted tours ever made.

Muncie will start the new year with a panel discussion built around some outstanding members of the section. Thursday, Jan. 15, is the date. Dinner will be served at the Ball State Student Center at 6:30 pm. The panel discussion will start at 7:30. D. G. Browne of the Broderick Co. will serve as moderator. The panel will consist of F. E. Jolliffe of Warner Gear Div., G. Rude of 3M, and P. J. Infante of Kimble Glass Co.

NEW HAVEN . . . The second meeting of the year was held at the Winchester Club House. Chester Gadzinski gave a very interesting talk on "Group methods of solving quality problems."

OMAHA-LINCOLN . . . The October meeting was held in Lincoln with 20 members and seven guests attending. Herschell Harrison, QC supervisor for Collins Radio Co., gave a very informative talk on "The installation of an SQC program."

PARKERSBURG . . . Richard S. Bingham, Jr. of The Carborundum Co. spoke at our October meeting. Twenty-eight members and guests were present to enjoy an insight to experimental design.

Dr. E. T. Hellebrandt of Ohio University was the November meeting speaker. His subject was "Mathematical analysis—techniques of decision making."

Larry Parker of the Dupont Co. has been appointed chairman of the educational committee. Larry expects to announce dates and instructors for the basic and advanced courses to start the first of the year.

PENSACOLA-MOBILE . . . Seventy-eight members and guests attended the October meeting. The program was arranged by the educational committee and consisted of three presentations running concurrently. Program A was presented by L. R. Henry of Pensacola Junior College on basic control charts; Program B was a presentation by Mr. Chapdelaine of Brookley Air Force Base on the use of electronic computers in SQC; Program C, Part I was presented by Lt. Col. J. R. Forrester of Brookley AFB on the relationship of reliability and QC; and Program C, Part II was presented by M. A. White of Brookley AFB on sampling procedures for reliability testing.

PHOENIX . . . J. G. Sorauf has been appointed chairman to fill the vacancy due to the resignation of R. T. Lorren.

A tour of Airesearch Mfg. Co. gave the members an opportunity to see many QC principles in action. The use of statistical presentations attracted the attention of many members.

The November meeting was held at Reynolds Metals Co. Following a plant tour of the aluminum extrusion plant, Reynolds' chief inspector spoke on "Inspection and QC as applied at Reynolds Metals."

PITTSBURGH . . . The Oct. 28 meeting was a plant tour of the Westinghouse Electric Corp. semi-conductor plant at Youngwood. Larry Jones, QC supervisor, was in charge. The group of about 40 members and guests heard a talk on the manufacturing of transistors, silica and germanium diodes, and rectifiers prior to the tour.

The Jan. 27 meeting will be held at the Wood Street YWCA and as usual dinner will be at 6:30 prior to the regular 8 pm meeting. The speaker is W. D. Fitzpatrick of Harbison Walker Refractories Co. and his topic is "QC in the manufacture of refractories."

Preparations have been made for the Jan. 29-30 meeting of the Metals Technical Committee with the section acting as host. This meeting will be of a problem solving nature.

The Oct. 8-9 meeting of the Metals Technical Committee was held at Albany, N. Y. Phil Schneider acted as moderator.

PITTSFIELD . . . Over 40 members were present Oct. 8 to hear C. M. Ryerson, RCA, speak on "Reliability and the QC engineer." Fundamental concepts of reliability were discussed as well as specialized problems and the meeting was enjoyable as well as educational to all members.

On Oct. 29-31 the section was host to the 12th annual New England QC Conference at the Wendell Sherwood Hotel. Over 380 members attended the conference which featured excellent technical sessions, an educational series, several plant tours, and a management seminar led by Dorian Shainin, Len Seder, and Allin Deacon. One of the highlights was the address given at the annual banquet by Robert C. Sprague, Sprague Electric Co. Mr. Sprague's talk was entitled "Certain aspects of our national security." A two day tour of cultural and industrial centers of Berkshire County comprised a part of the active ladies' program. Frederick C. Hartwell of Peter J. Schweitzer, Inc. was general chairman of the highly successful conference.

PORTLAND . . . Robert B. Menstell, American Can Co., has taken over the duties of chairman for the coming Northwest Conference to be held Mar. 27-28 at the New Museum of Science and Industry. Dr. Worthington, director of food technology at Oregon State College, has been assigned the duties of preparing an educational format that will attract and maintain the attention of those interested but uninitiated in the ways and means of QC. Dr. Worthington will be assisted by Henry Blood and Ray Vanderzanden.

Loren Austin, Boeing Aircraft, ably substituted for Dr. Butterbaugh as speaker at the Nov. 4 meeting. Overseas commitments prevented Dr. Butterbaugh's return in time for the meeting. Mr. Austin presented a very excellent program on the applications of QC.

RHODE ISLAND . . . On Oct. 16 Truman W. Read, Hamilton Standard Div., United Aircraft, gave a very interesting talk on "Continuous lot plot and VOSP procedures."

R. Shaw Goldthwait was elected chairman of the New England Council at a meeting held during the recent 12th New England QC Conference in Pittsfield.

ROCHESTER . . . The food and beverage sub-group conducted two plant tours during October. About 30 people visited the Tobin Packing Co. where they were cordially received. All phases of meat processing and packing were observed. The Knox Glass Co. hosted 18 guests who traveled to Knox on Oct. 24. The next day they were conducted through plants at Knox and Parker, Pa. In the evening they were guests of Knox at a banquet.

On Oct. 21 Len Seder treated a well attended meeting to some interesting phases and possibilities in his "Impact of QC on consumer-vendor relationships."

The gaging and measurement sub-group will meet on Jan. 6 with a representative of the New York Air Brake Co. to discuss "Precision measurement in mass production methods."

Robert Lusser, the internationally known expert on rockets and missiles, will be guest speaker at the Jan. 15 meeting. Mr. Lusser will have some very interesting methods for "Achievement and maintenance of reliability."

ST. CHARLES . . . W. E. Jones, Management Controls, addressed a dinner meeting held at the Club Arcada on Oct. 21. Mr. Jones spoke on "QC applied to automated assembly operations.

A plant tour of Shakeproof Div., Illinois Tool Works, Elgin, will be sponsored by the section.

On Jan. 20 Henry J. Becker, American Steel & Wire Div., U. S. Steel Corp., will address a dinner session at the Club Arcada on the subject "Statistical SQC applications in metallurgy." A pre-dinner educational seminar on the subject "Process controls—variables" will be conducted by Prof. H. R. Swenson, Illinois Institute of Technology. The seminar will start at 4 pm, followed at 5:30 by a social hour with dinner being served at 6:30 pm.

ST. LOUIS . . . A "management night—bring your boss" program was held on Oct. 15. The speakers were Rear Admiral Lloyd Harrison (USN, Ret.), and H. Earle Moore. The meeting was a joint one with the St. Louis section of the Society for Advancement of Management.

The St. Louis conference was held during the month of October and was highly successful.

SALT LAKE CITY . . . The section regrets the resignation of chairman Vern Shulz who has moved from the area. This necessitated a realignment of officers. Vice chairman Cecil McCarty moved into the chairman's position and John Boyd (a former chairman of the Tennessee section) was unanimously elected vice chairman.

The second meeting of the season was held at the University of Utah Union Building on Oct. 30. The pre-meeting educational series featured the second lecture in the series of educational discussions. It was presented by Joseph Kirton, Hill AFB, and covered the subject "Simple illustration of chance of development of laws of combinations summarized by Sterling's formula." The guest speaker was Bruce Adams, Sperry Utah Engineering Laboratory. He presented a very interesting lecture on "Inertial guidance" pointing out the key position of quality personnel in assuring performance within fantastically small tolerances.

Joseph Kirton, section secretary, recently completed three months' training at Boeing Aircraft Co., Seattle. The course covered QC procedures of the Bomare IM-99 missile.

SAN ANTONIO . . . A cocktail party and social session preceded the second annual "management night" banquet meeting held Oct. 7 in the Walnut Room of the Hilton Hotel. Thirty-eight members and guests were privileged to hear Society Vice President J. Y. McClure, manager of QC of Convair-Fort Worth, speak on the timely subject "Management's responsibility to QC." In view of the lively discussion period following Mr. McClure's address, nothing more can be said except that this meeting was most effective and successful. Eleven distinguished guests from the "top-level" segments of management affiliated with local industry and government facilities were honored guests for this event.

SAN DIEGO . . . A year has passed since the concept of integrated or "co-ordinated planning" was brought to the attention of the section. At that time, one of the liveliest discussions ever recorded in the section ensued.

Now we are ready for a progress report. The meeting this month will feature a panel again led by R. W. Allen, QC manager for Solar Aircraft. The subject will be "Co-ordinated planning—pros, cons, and progress." Other panel members will represent inspection, engineering, and production.

In essense, "co-ordinated planning" combines production and inspection travelers into a unified, streamlined form. The resulting "paper" embodies the finest type of co-ordination and cooperation.

SAN FRANCISCO BAY AREA . . . A joint meeting with IRE and PGRQC was held Oct. 13 at the Villa Chartier Garden Room. A very interesting and informative talk on "Some aspects of the reliability problem in nuclear

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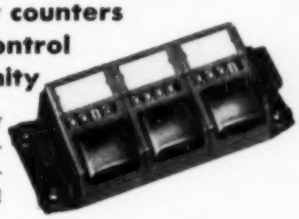

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SECTION	DATE	PLACE	TIME	SUBJECT	SPEAKER
Allentown-Bethlehem	Jan. 14	Hotel Traylor	8:00 pm	Local Participation Night	———
Baltimore	Jan. 20	Memorial Stadium	8:15	Sampling Tax Returns	Dr. A. C. Rosander, Internal Revenue Service
Binghamton	Jan. 20	Elks Lodge 852	7:00	The Story of the Cutting Edge	The DoALL Company presentation
Birmingham	Jan. 16	Hotel Stafford, Tuscaloosa	6:30	Reliability Problems in QC	Wyllys G. Stanton
Boston	Jan. 8	Carter Ink Co., Cambridge	2:30	Process Control (plant tour)	William Grady, Carter Ink Co.
Buzzards Bay	Jan. 14	Continental Screw Co.	8:00	Quality Control	C. W. Carter, Rath & Strong, Inc.
Chattanooga	Jan. 6	Hotel Patten	6:30	Local Plant Tour	———
Chicago	Jan. 14	Furniture Mart	5:00	Sampling Tables for Inspection	Peter Kuffner, U. S. Air Force
				Administration of an Inspection Program	Henry J. Jacobson, Sutherland-Jacobson & Associates
Cincinnati	Jan. 21	Engineering Society Bldg.	8:00	QC and OR	Dr. Frank E. Grubbs, Aberdeen Proving Ground
	Jan. 31	Hotel Sinton	———	8th Annual All-Day Conference	———
Cleveland	Jan. 9	Cleveland Eng. & Scientific Center	8:00	Random Balance	Dorian Shainin, Rath & Strong, Inc.
Columbus	Jan. 21	Jeffery Mfg. Co.	8:00	The Evolution of the Legal Aspects of Quality	John W. Gower
Corning-Elmira	Jan. 12	Hotel Langwell, Elmira	7:00	Performing Capability Studies	Harmon S. Bayer, Consultant
Dallas-Fort Worth	Jan. 15	Arlington State College, Arlington	8:00	The Design of Experiments	Dr. E. F. Moore, Astrodyne, Inc.
Dayton	Jan. 8	Delco Products Lodge	8:00	Social Meeting	———
Delaware	Jan. 8	Lord De La Ware Hotel, Wilmington	8:00	The Sales Forecast—Past, Present, and Future	Andy Rodger, International Latex Corp.
Evansville-Owensboro	Jan. 20	Owensboro	7:30	QC Applications in the Distilling Industry	Robert H. Mayes, Shenley Industries
Greater Muskegon	Jan. 8	Bill Stern's Seak House	6:30	Plant Visitation, Norge Div., Borg-Warner Corp.	———
Hamilton	Jan. 8	Westinghouse Auditorium, West End Plant	8:00	Fundamental Consideration in Starting QC	John B. Pringle, Bell Telephone Co.
Hamilton-Middletown	Jan. 14	Anthony Wayne Hotel, Hamilton	6:30	Design of Experiments	Charles Bicking, The Carborundum Co.
Harrisburg	Jan. 7	The American Legion, Elizabethtown	6:30	Design and Analysis of Industrial Experiments	Dr. Allen Crawford, Esso Research & Engineering Co.
Hartford	Jan. 20	Club Alden	6:30	The Scope of QC	Warren R. Purcell, Raytheon Mfg. Co.
Huntsville	Jan. 30	Decatur	———	Nature of QC	Edward Balog, U. S. Steel Corp.
Indianapolis	Jan. 20	Atherton Center, Butler University	6:30	Professionalism in QC	Henry J. Jacobson, Sutherland-Jacobson & Associates
Kankakee-Joliet	Jan. 12	Jensen's Cafe, Kankakee	7:00	Application of QC to Industry	L. R. Stickler, R. R. Donnelly Co.
Kansas City	Jan. 17	Johnson County Community Center	———	Winter Social Evening	———
Los Angeles	Jan. 3	Rodger Young Auditorium	6:00	Paperwork, Clerical and Accounting Applications in QC	Glen E. Ghormley, Cannon Electric Co.
Metropolitan	Jan. 15	Hotel Shelburne, New York City	6:30	ASQC—its Objectives and its Program (annual dinner meeting)	C. E. Fisher, Bell Telephone Laboratories, Inc.
			———	People—as it Pertains to QC	Simon Collier, Johns Manville Sales Corp.
	Jan. 24	Stevens Institute of Technology	———	Annual All-Day Chemical Conference	———
Mid-Hudson	Jan. 6	Nelson House, Poughkeepsie	7:00	How Management Uses QC to Reduce Operating Costs	Dorian Shainin, Rath & Strong, Inc.
Milwaukee	Jan. 19	Stratford Hotel	6:00	Operations Research	Wm. Golomski, Oscar Mayer & Co.
Montreal	Jan. 14	CIL Bldg.	8:15	Practical Applications of Probability Paper	R. Cardno, Canadian General Electric
Muncie	Jan. 15	Student Center	6:30	Panel Discussion	D. G. Browne, F. E. Jolliffe, G. Rude, P. J. Infante
Northeastern Indiana	Jan. 8	Chamber of Commerce, Fort Wayne	8:00	How Gages Fit into QC Procedures	Harry Kiefaber, The Sheffield Corp.
Omaha-Lincoln	Jan. 9	———	7:00	———	———
Pittsburgh	Jan. 27	Wood Street YWCA	8:00	QC in Manufacture of Refractories	W. D. Fitzpatrick, Habison Walker Refractories Co.
Pittsfield	Jan. 14	Stanley Club	6:45	Ladies' Night	———
Rhode Island	Jan. 15	Providence Engineering Bldg.	8:00	Cost Shooting—Now Ready for Managers to Use	Dorian Shainin, Rath & Strong, Inc.
Rochester	Jan. 6	Chamber of Commerce	6:15	Precision Measurement in Mass Production Methods	———
	Jan. 15	Chamber of Commerce	6:15	Achievement and Maintenance of Reliability	Robert Lusser, Redstone Arsenal
St. Charles	Jan. 20	Club Arcada	4:00	Process Controls—Variables	Prof. H. R. Swenson, Illinois Institute of Technology
				SQC Applications in Metallurgy	H. J. Becker, American Steel & Wire Div., U. S. Steel Corp.
St. Louis	Jan. 21	Golden Fried Chicken Loaf Restaurant	6:30	Professional Development of QC Engineers	C E. Fisher, Bell Telephone Laboratories, Inc.
San Antonio	Jan. 13	Hilton Hotel	8:00	How Managements Have Drastically Reduced Management Costs	Dr. E. J. Moore, Astrodyne, Inc.
South Bend-Mishawaka	Jan. 15	Bendix Legion Post	7:30	SQC on Short Runs	Herschell Harrison, Collins Radio Co.
Syracuse	Jan. 27	Turn Hall	6:30	Modern Use of the Range	R. S. Bingham, Jr., The Carborundum Co.
Toronto	Jan. 7	University of Toronto	8:00	Workable QC Methods in the Jobbing Shop	D. Albert, Norma Hoffman Bearing Corp.
	Jan. 21	Sign of the Steer	6:30	QC as Related to Management and Employee	Simon Collier, Johns Manville Sales Corp.
Tucson	Jan. 22	———	———	Audit Sampling	Warren R. Clemens, Hughes Aircraft Co.
Tulsa	Jan. 19	Borden's Sky Room, Sheridan Village	7:00	Vendor QC Evaluation Program	J. Y. McClure, Convair-Forth Worth
Univ. of W. Ontario	Jan. 14	Stratford YMCA	8:00	Local QC Problems	J. E. Crossman, Raytheon (Canada) Ltd.
Utica	Jan. 13	———	7:00	———	———
Washington, D. C.	Jan. 28	Occidental Restaurant	8:00	Application of SQC in the Food Industries	Howard L. Stier, National Canners Association
Windsor	Jan. 14	Assumption University	8:00	QC Applications in Warranty Analysis	M. Lightstone, Chrysler Corp.
Youngstown	Jan. 19	Astoria Cafe, Warren	8:00	Nationwide Dialing by 1965	Ralph Riefenstahl, Ohio Bell Telephone Co.

weapons'' was given by Dr. Louis J. Paddison, Sandai Corp. He discussed the methods involved in the development of techniques which would reduce the human effort in manufacturing, stockpiling, and field utilization.

The section has an added program attraction this year in the form of an educational series on probability. Four lectures by various guest lecturers have been planned by education chairman Dr. Benjamin Epstein of Stanford University. All sessions are on an informal basis designed to stimulate discussion, increase professional competency, and provide a clearer understanding of the fundamentals of probability. The first lecture, attended by 31 members and guests, was held Oct. 23, 8-9:30 pm at Stanford University. The dates for the remaining lectures are Dec. 18, Feb. 19, and Apr. 23.

SOUTH BEND-MISHAWAKA . . . A forum meeting on the subject of ''In plant training—how much, how often'' was held Nov. 13. The meeting took the form of a panel discussion followed by a floor discussion. Forum meetings have been planned for four of our programs this year thus giving members and guests a chance to discuss their own problems with local users of SQC and related techniques.

Allin P. Deacon, Deacon & Associates of Brantford, Ont., was guest speaker on Nov. 20. Mr. Deacon is especially interested in SQC for small plants and gave a very interesting talk.

We have no December meeting due to conflicts raised by the holidays.

SOUTHERN CONNECTICUT . . . The members enjoyed the November meeting which consisted of a plant tour of the Sikorsky Aircraft Co. The tour covered the basic manufacturing area. This was followed by a technical session and social period at the Mill River Country Club in Stratford. The highlight of the evening was the guest speaker. Dr. Thomas H. Chilton, technical advisor to the engineering department of E. I. Dupont de Nemours & Co., presented ''Engineering today and tomorrow'' which was very well received. The comments following his talk were very enthusiastic.

Howard Burbank, section vice chairman, spoke on ''Cost reduction aspects of QC'' at the 12th New England QC Conference. Sam Oliver was re-elected treasurer of the New England Conference Council at elections held during the conference.

SOUTH TEXAS . . . On Oct. 8, J. Y. McClure of Convair-Fort Worth spoke on ''Management's responsibility to QC'' which was a very timely subject and one which evoked some good discussion.

TENNESSEE . . . As promised, here is the final on the Sept. 22 section organizational meeting in the Tri-Cities area. Of the 96 persons who attended, 35 either have membership applications already admitted or being processed. A second meeting will be held soon to elect officers and to complete the formal section application.

On Oct. 22, R. S. Bingham, Jr. of the Carborundum Co. spoke to a group of section members and members of the statistics club of the University of Tennessee. The topic of his very informative talk was ''The use of statistics in laboratories and researching industries.''

Beginning this month, your reporter will list in each issue the names of the new members of the section. A warm welcome this month is extended to Dr. Lewis Copeland of the University of Tennessee, Knoxville, and to Robert E. Odom of Alladdin Industries, Inc., Nashville.

TOLEDO . . . Dr. Max Astrachan, Wright Patterson AFB, spoke to the section on Oct. 9. The talk was very informative as Dr. Astrachan gave a very concise explanation of MIL-STD-414 in addition to the technical aspects of variable sampling. The meeting was held at the Toledo Yacht Club and was preceded by dinner.

TORONTO . . . During the October meeting held at the University of Toronto, a double feature was presented by Dr. J. H. Davidson. After a short talk ''Statistical methods and industrial engineering,'' we were conducted on a most interesting verbal tour 'behind the Iron Curtain' and pictorially illustrated by slides produced from photographs taken during his recent visit to Russia.

Members who attended the recent visit to Quality Records, Ltd. were unanimous in their appreciation of the efforts made by the company to insure a successful evening. The tour, preceded by refreshments, provided ample demonstrations of the controls exercised during the various operations involved in the production of a superior quality record.

During Christmas week a stag will be held for members of both the executive and forum committees.

TUCSON . . . John R. Albright, district manager of Mountain States Telephone & Telegraph Co., spoke at the Oct. 30 meeting on the quality of service provided by his organization. Among recent improvements in the QC of such service has been a rapid reading course to increase the skill of information operators and the setting of QC limits for answers to ''operator'' calls and service calls. Telephone company service analysts continuously monitor a two percent sampling of all calls to the company to make sure that correct, courteous information is given and that promises or agreements made are followed through and kept.

Election of new section officers also took place at this meeting. The results are: chairman—Mark Manning, vice chairman—Warren R. Clemens, secretary—R. O. Sprague, and treasurer—W. J. Anderson.

TULSA . . . The basic QC course initiated in September has a 60 student enrollment. It is being conducted at one of the local high schools.

The speaker for the Jan. 19 meeting will be J. Y. McClure, Convair-Fort Worth. The topic of the meeting, to be held in the Sky Room of Borden's Cafeteria at 7 pm, will be ''A vendor QC evaluation program.''

Plans are in progress for an all-day forum to be held at the Alvin Hotel on our anniversary date—Apr. 4, 1959. A successful forum is anticipated. Wendell Barnes of the Small Business Administration will be the noon luncheon speaker. A military panel comprised of members from the Air Force, Army, and Navy will be moderated by John Reardon, Office of Chief Ordnance. Reserve this date now!

Tucson Section-Hughes Aircraft Company Sponsor "Surprisingly" Successful Practical SQC Course

An educational program being sponsored by the Tucson section and Hughes Aircraft Co. has proved to be a very successful venture—and a rewarding one for the section which has thus far been awarded 944 points in the Saddoris Award competition for this activity. Here's the story.

Last spring some of the Air Force and Hughes Aircraft Co. representatives got together with Fred Ennerson after a section meeting and requested a course in SQC methods. Mr. Ennerson has a fine reputation for emphasizing the practical applications of SQC in all levels of production and it was felt that this approach was what was wanted. It was agreed that the course would be given afterhours because of scheduling problems.

The proposed course was not publicized very widely at first—a small notice appeared on a few of the bulletin boards and no mention was made in the company newspaper. Attendance at the course was to be voluntary with no textbook or tuition involved. The group would meet from 4:30-6:00 one night a week.

To the surprise of everyone concerned, over 300 people enrolled. Four classes had to be organized. Mark Manning, another section member and a QC engineer at Hughes, aided Mr. Ennerson in conducting the classes.

To date, 159 people have successfully completed the 10-week course in basic "Practical SQC" and 23 additional students have completed a 6-week advanced course and other classes are still in progress.

Another surprising thing about the course was the participation of departments other than QC. A total of 46 different Hughes departments have been represented.

Some clear cut conclusions as to how to run a SQC training program have emerged.

1. More people with varied individual interests will sign up for a short practical course, especially if they do not have to pay tuition or buy a textbook.
2. The in-plant location and early evening hour are most convenient from the standpoint of transportation costs and interference with other after-working-hours activities.
3. Award of a certificate and notation in the individual's personnel history record is an important facet.

Further information on Tucson's successful handling of this program can be obtained from Ella Scofield, Saddoris Award Chairman, 1310 S. Treat Ave., Tucson, Ariz.

UNIVERSITY OF WESTERN ONTARIO . . . A panel discussion on the relationship between time study men and QC attracted more than 70 members and guests to the Oct. 8 meeting held at the Radio-TV plant of Dominion Electrohome Industries, Ltd., Kitchener. Panel members were: time study side—J. D. Sim, of Dominion Rubber Co., Ltd. and Albert Chapman, Dominion Electrohome Industries, Ltd.; quality control side—Herbert Markle, Leland Electric (Canada), Ltd. and Neil McCarthy, Canadian Westinghouse, Ltd. Allin P. Deacon of Deacon and Associates served as moderator.

It was concluded that, with cooperation between the two groups, the goal of high quality at low cost could be achieved.

UTICA . . . An analysis of the attendance records of the October meeting conclusively proved that people do prefer Utica Club 2 to 1. A large turnout of members and guests visited the West End Brewing Co. F. X. Motts, II, president, and R. Berner, brewmaster, conducted the groups. After the tour and a buffet supper, courtesy of Mr. Motts, a discussion on quality problems of the brewing industry was led by Messrs. Motts and Berner. To give the discussion more meaning, sampling of the product by all attending was conducted.

At the business meeting period, plans were discussed for Dr. Robert Lusser's visit. Following the business session, a QC problem about significant differences was discussed and solved.

WASHINGTON, D. C. . . . With 107 members on the rolls, the section boasts its largest membership for this date.

The Oct. 22 meeting had as its speaker Bob Brousseau of AT&T. Mr. Brousseau gave a highly informative talk on the selection of sample size based on desired precision and confidence and the approximate geometrical configuration of the expected distribution. He showed how the configuration can be expressed as a common figure such as a triangle or trapezoid and left little doubt of the monetary savings available to experiment planners using the geometrical method. Also discussed was the coming 3rd Annual Administrative Applications Division Conference to be held in Washington on Mar. 5-6.

The remainder of the section's meetings will be held at the Occidental Restaurant.

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WICHITA . . . On Oct. 7, the Southwestern Bell Telephone Co. presented a 30-minute film on "Micro-wave techniques." The dinner meeting was held at the Skirkmere Hotel.

WINDSOR . . . F. H. Howard, General Motors Diesel, Ltd., presented "QC in locomotive manufacture" at a recent meeting. The transition from steam to diesel power was discussed and the subsequent problems were reviewed. Work simplification and QC worked together to ease the clerical work of the inspectors, thus giving QC a wider scope in which to apply statistics. Scrap and rework has been reduced and a high quality has evolved from this close cooperation with industrial engineering and QC. Roy Mackay moderated the discussion period during which the speaker further proved his methods. Don Malott thanked the speaker on behalf of the section.

Bill Moggridge and his committee are planning an interesting and informative program for the 1959 QC forum.

YOUNGSTOWN . . . On Oct. 2 Stanley B. Sherwood of General Motors' production engineering section spoke to some 70 members and guests on "Machine capability—a common language tool." After defining the relatively new concept of machine capability, Mr. Sherwood enumerated the advantages of knowing the capability of a machine. Recommendations for the proper approach to capability studies were based on the personal experiences of master mechanics and QC engineers of General Motors. Mr. Sherwood emphasized the need for improving understanding of machine capability benefits to product design engineers in designing future products. As supervisor of QC committees at GM, Mr. Sherwood was well qualified to explore the final portion of his subject—methods and means of evaluating machine capability.

SIGNIFICANT DIFFERENCES

. . . Allentown-Bethlehem—Dick Wetherhold has been promoted to supervisor of inspection at Air Products, Trexlertown.

John Nemeck, our all-day conference chairman, was promoted to operating supervisor in the transistor department at Western Electric, Allentown.

Bob Krug, our exhibit chairman, has been promoted to program planner at the Laureldale plant of Western Electric.

. . . Binghamton—We of the Binghamton section will miss the smiling face of Charlie Rubin, past chairman, director, and one of the most active section members, who has left Binghamton to become manager of QC at W. L. Maxson Corp., Old Forge, Pa. Under Charlie's able direction last year we were successful in winning the ASQC Saddorris Award.

The welcome mat goes out to welcome Mike Drabo of Link Aviation to a director's seat on the executive committee.

. . . Boston—Recent position changes among section members are as follows: Roger H. Gill, foreman, Raytheon Mfg. Co., Newton; Herschel N. Hadley, assoc. reliability engineer, Area Research & Dev., Wilmington, Md.; David J. Harrigan, div. supvr. of quality inspection, Receiving Tube Div., Raytheon Mfg. Co., Quincy; William B. Hathaway, Jr., QC engineer, Joseph Pollack Corp., Dorchester; Francis W. Heintz, QC manager, Power Tube Div., Raytheon Mfg. Co., Waltham; and George W. Henderson, supervisor, Western Electric Co., Lawrence.

. . . Chicago—The section is in need of an electronic-automatic post office box checker-looker-taker outer. Charles Matz of Commonwealth Edison, who had assumed this duty in addition to all of his other ASQC activities, received a promotion and will now be working in a Chicago suburb instead of the loop.

. . . Cincinnati—D. A. Brandt was guest speaker at the St. Louis meeting of the Institute of Food Technologists on Oct. 20.

. . . Cleveland—On Oct. 20 a group of 12 statisticians from Yugoslavia visited Cleveland. After listening to a talk by Charles Joseph, Jr. on "QC organization and management," the group spent an interesting afternoon going through the Ford Motor Co. foundry.

. . . Corning-Elmira—Alan Stone, vice chairman and past treasurer of the section, has become QC supervisor of the pressware plant of the Corning Glass Works.

Stuart Frankel is now QC supervisor of "A" Factory of the Corning Glass Works.

. . . Dallas-Fort Worth—Congratulations to the following members on their recent promotions: Charles M. Brown and Leslie T. Rankin to QC engineer, and Edwin H. Starns to QC representative.

. . . Danville-Sunbury—George Simmons, our immediate past chairman, has assumed new responsibilities in Columbus, Ohio with the Quartermaster Corps.

Presence of our chairman Jay Wagner at the October meeting was noted by many. Jay has been absent due to recent surgery and all hope for a speedy recovery for him.

. . . Hartford—Ken Martin has been appointed chief inspector of the Holo Krome Screw Corp.

Harold Hamilton, of Hamilton Standard and former section treasurer, is recovering from a serious illness at Hartford Hospital.

Dorian Shainin of Rath & Strong, Inc., was speaker at a meeting of the Society of Automotive Engineers at Bradley Field on Oct. 7.

Stan Straska has been appointed QC manager of Royal McBee's new portable typewriter plant at Springfield, Mo.

Pennell H. Embleton, quality control supervisor of Veeder-Root, Inc., contributed the section on QC to the booklet "Planning Your Future in Connecticut Industry." This booklet discusses 27 various careers and is distributed to secondary schools by the four major electric utilities in Connecticut as a public service.

. . . Los Angeles—R. L. Carver and G. M. McGinnis have joined the QC staff at Autonetics, A Division of North American Aviation, Inc. Mr. Carver has been assigned to quality engineering of inertial guidance instruments while Mr. McGinnis will serve as head QC statistician.

Fred Borggeve, formerly of Firestone Missile Corp., is now with the Nortronics quality engineering department.

. . . Milwaukee—H. G. Thompson, who was chairman of the section's professionalism committee, has resigned from the John Oster Co. and joined the Crane Co., Chicago.

Dale Cue has resigned as assistant to director of QC, A. O. Smith Corp. to assume duties as quality manager, Hoover Ball and Bearing Co., Ann Arbor, Mich.

. . . Pittsburgh—Samuel Shapiro, formerly with Pittsburgh Plate Glass Co., has left the area and is now in Schenectady, N. Y.

R. F. Gieselman has been transfered by Westinghouse Electric Corp. to their Bloomington, Ind. plant.

Harry Kraff, formerly of Chicago, has joined the Westinghouse Electric Corp. Bettis Field plant as a QC engineer.

. . . St. Louis—D. F. Sager has been promoted to plant manager at the Newark, N. J. brewery of Anheuser-Busch.

. . . Salt Lake City—Vern Shulz, recently elected chairman, has been transferred from the Ogden plant of Marquardt Aircraft Co. to the headquarters office at Van Nuys, Calif.

. . . Tennessee—Prof. David Chambers is traveling considerably these days. During October he was guest speaker at the meeting of the Nashville chapter of the American Institute of Industrial Engineers. He also spoke at the annual QC conference at the University of Alabama and the Memphis section's meeting and will be at the Technical Division Annual Conference to be held in Charlottee during January.

. . . Toronto—Negotiations are presently underway with the Canadian Broadcasting Company to investigate the possibilities of promoting, through the medium of their program "Tabloid," a better understanding by the public of the activities and ideals of ASQC.

. . . Utica—Richard Pilger has been appointed specialist-vendor materials for the General Electric Radio Receiver Department.

DR. STEFANO OBERTO

November 19, 1906—October 3, 1958

Dr. Stefano Oberto died suddenly on the third of October. He was one of the most enthusiastic members of ASQC and one of the strongest proponents of SQC in Europe. He worked hard at implementing the ideas and principles of SQC and of spreading them throughout Italy.

Dr. Oberto was a doctor in physical science and a rubber technologist since 1939. He became assistant director of the rubber laboratory group of the Pirelli Co. in 1946 and director, operations research in 1954, the position he held at his death.

He was vice president of the Milan chapter of AICQ, a fellow of IRI, a member of ACS, ASQC, ORSA, and many others.

clinics, conferences, and courses

DECEMBER

. . . ***29-30***—Section M (Engineering) of 125th Annual Meeting of AAAS, Washington Statler Hotel, Washington, D. C., sponsored by American Association for the Advancement of Science, contact Secretary, Section M (Engineering), AAAS, c/o Engineers Joint Council, 29 West 39th St., New York 18, N. Y.

JANUARY

. . . ***12-14***—Fifth National Symposium on Reliability and Quality Control, Bellevue-Stratford Hotel, Philadelphia, Pa., sponsored jointly by ASQC, AEEI, IRE, and EIA, contact James Rivera, RCA Service Co., Government Service Dept. 204-1, Cherry Hill, Camden 8, N. J.

. . . ***20***—Sixteen-week program on principles and procedures in precision measurement, University of Illinois, Navy Pier, Room 218, Chicago, Ill., sponsored by Chicago section of ASQC.

. . . ***24***—Annual One-Day Stevens Chemical Conference, Stevens Institute of Technology, sponsored by Metropolitan section of ASQC.

. . . ***26-30***—Three concurrent intensive courses (advanced QC and statistics; advanced motion and time study; and linear and mathematical programming), Washington University, St. Louis, Mo., contact University College, Washington University, St. Louis 5, Mo.

. . . ***26—Feb. 5***—Twelfth Annual Short Course in QC by Statistical Methods, University of Illinois, Urbana, Ill., contact Prof. John A. Henry, Room 205, Mechanical Engineering Laboratory, University of Illinois, Urbana, Ill.

. . . ***27-30***—15th Annual SPE Technical Conference, Hotel Commodore, New York, N. Y., sponsored by Society of Plastics Engineers, contact William C. Cleworth, Publicity Chairman, 15th Annual SPE Technical Conference, 342 Madison Ave., New York 17, N. Y.

. . . ***29-30***—ASQC Metals Technical Committee Meeting.

. . . ***31***—Eighth Annual All-Day Conference, "E.A.S.E. of QC," Cincinnati, Ohio, sponsored by Cincinnati section of ASQC.

FEBRUARY

. . . ***3***—Quality Control Management and Engineering 15-week course, University of Rhode Island, Division of University Extension, Providence, in cooperation with the Rhode Island section of ASQC, contact Alberto J. La Greca, 20 Fenwood Ave., Esmond 17, R. I.

. . . ***6-7—Middle Atlantic Conference, Traymore Hotel, Atlantic City, N. J., sponsored by ASQC, two-day conference featuring four simultaneous sessions with papers and discussions covering all phases and applications of SQC, for registration blank and detailed program write J. L. Freeman, General Motors Corp., Boxwood Rd., Wilmington, Dela.***

. . . ***6-7***—Eleventh Annual Industrial Engineering Institute, conducted simultaneously on the Berkeley and Los Angeles campuses of the University of California, contact Department of Conferences, University Extension, University of California, Berkeley 4 or Los Angeles 24, Calif.

MARCH

. . . ***27-28—Pacific Northwest QC Conference, New Museum of Science & Industry, Portland, Oregon, sponsored by ASQC.***

Correction Notice

In a recent article by Kalman Joseph Cohen ("Determining the 'Best Possible' Inventory Levels," Vol. XV, No. 4, October 1958) a transposition of figures occurred. On page 5 of the article, the engraving shown as Figure 2 should have appeared with the Figure 5 caption and the engraving shown as Figure 5 should have appeared with the Figure 2 caption.

Our apologies to Mr. Cohen and to our readers.

1959 MIDDLE ATLANTIC CONFERENCE

The Delaware section of ASQC is host for the 1959 Middle Atlantic Conference to be held Feb. 6-7 at the Traymore Hotel, Atlantic City, N. J. The theme of the conference is "Balanced Perspective equals Successful Quality Control."

Four concurrent sessions will be held covering such phases of SQC as basic techniques, management, production control, industrial engineering, operations research, administrative applications, and advanced techniques. The speakers enjoy a national reputation as recognized leaders in their respective fields and can be expected to present many new concepts and applications for those interested in the many facets of quality control work.

The highlight of the conference will be a panel session on the subject, "QUALITY CONTROL—INCREASING ITS EFFECTIVENESS AND PROFESSIONAL STATUS." National and international figures will participate in this truly enlightening and inspiring session. The moderator is Prof. E. R. Ott of Rutgers University. Panel members are: Dr. J. M. Juran, consulting management engineer; Dr. A. V. Feigenbaum, manager of quality control, General Electric Co.; O. E. Johnson, vice president-manufacturing, Bristol Myers Co.; and G. Fromm, vice president-manufacturing, International Latex Corp. This is a conference wide session with no other concurrent activity and something that no one will want to miss.

Registration blanks and detailed program may be obtained by writing J. L. Freeman, General Motors Corp., Boxwood Road, Wilmington, Dela.

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(As of Oct. 31, 1958)

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BUZALEWSKI, CHRISTINE A., Reading, Pa.
BYRNE, ROBERT B., Tulsa, Okla.
CANTERGIANI, GENO J., Tulsa, Okla.
CASTOWN, RUDOLPH W., New York, N. Y.
CHOWNING, GERVAISE, Covington, Ky.
DAVIS, RICHARD L., South Natick, Mass.
DAY, HENRY W., Detroit, Mich.
ENSIEN, WILLIAM W., Broken Arrow, Okla.
ERVING, JOHN M., S. Boston, Mass.
FRANK, ROBERT W., Tulsa, Okla.
FULLER, GEORGE T., Chicago, Ill.
HARTLEY, GEORGE N., Tulsa, Okla.
HARTWICK, CARWIN M., Stratford, Ont., Canada
HEIDEMANN, JOHN H., Cincinnati, Ohio
HUTCHINSON, HARRY M., Tulsa, Okla.
KING, RICHARD W., Glen Rock, Pa.
KRUGER, JOHN R., Wisconsin Rapids, Wis.
LONG, CHARLES F., Tulsa, Okla.
LOWE, R. ALAN, Findlay, Ohio
MARCINKEVICIUS, JOSEPH JR., Muskogee, Okla.
MARKS, GLENN E., Butler, Wis.
MCGOWAN, RICHARD T., Cincinnati, Ohio
MCNAIR, RAYMOND C., Tulsa, Okla.
MEYER, NED H., Celina, Ohio
MILLER, RAYMOND A., Tulsa, Okla.
MORATH, RAYMOND H., Cincinnati, Ohio
MYERS, DANIEL A., Erie, Pa.
NOLTE, ROBERT A., Cincinnati, Ohio
OVERPECK, BOYD H. JR., Orlando, Fla.
PAUL, WILLIAM H., Tulsa, Okla.
PETERS, CLETUS F., Cincinnati, Ohio
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WITTE, PAUL J., Norwood, Ohio
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(Continued on page 40)

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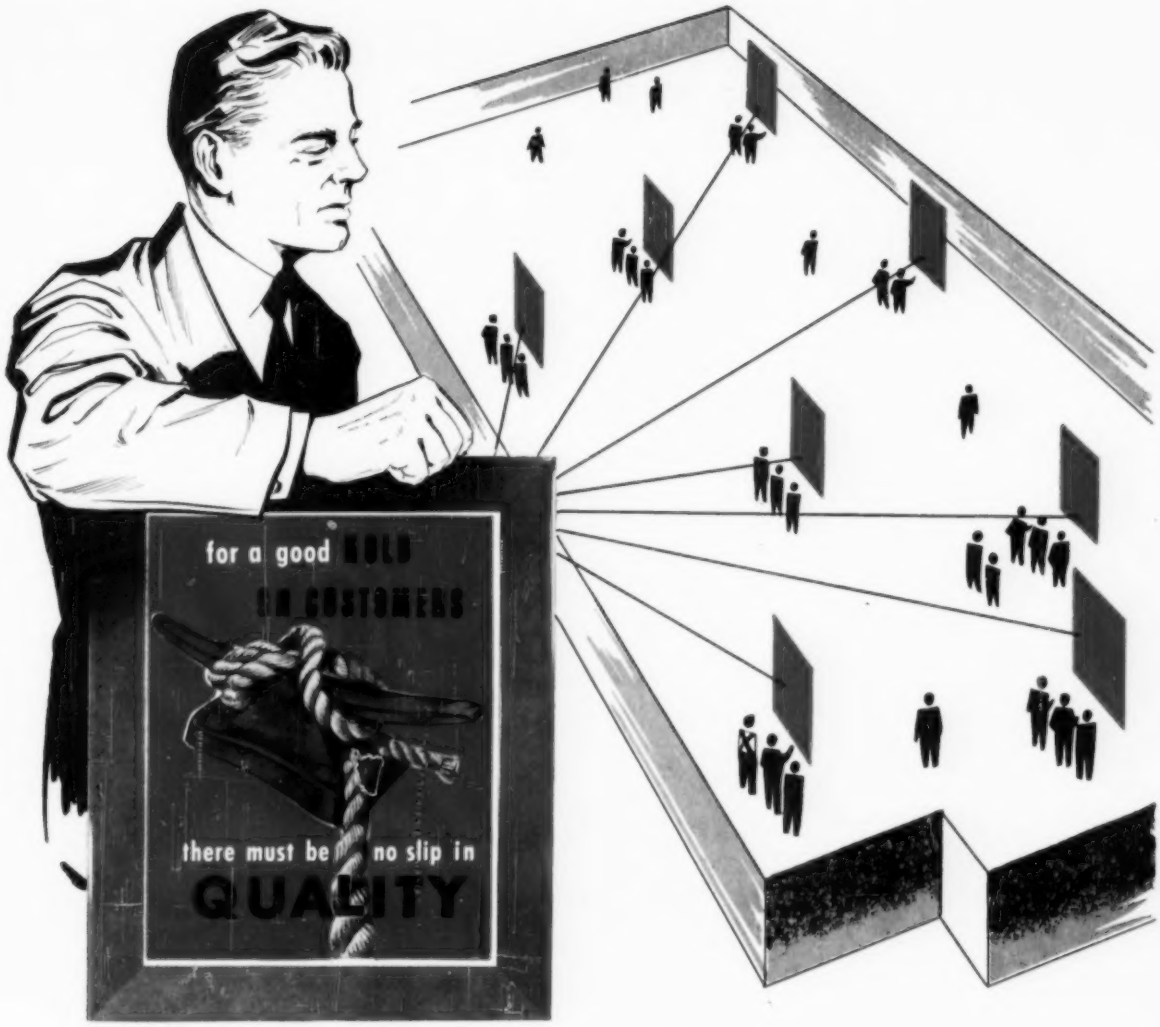

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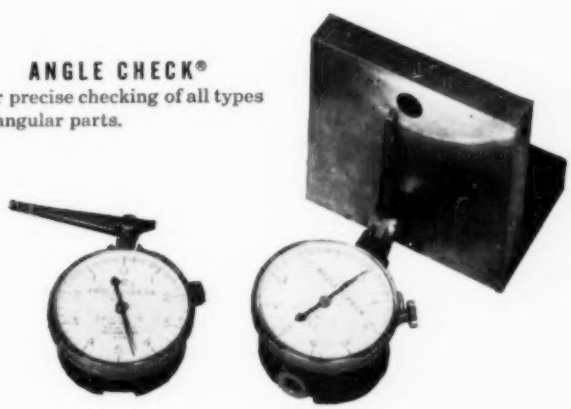

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